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THE OBJECTIVE PRESENTATION OF HARMONIC MOTION.

CONTENTS.

DESCRIPTION OF A WAVE MACHINE.*

1. *Introductory.* — Although wave machines of a variety of special patterns are well known, none of them, to my knowledge, are sufficiently comprehensive in design to embody in a single mechanism the types of harmonic motion met with in acoustics, light, electricity and elsewhere, with a clear bearing on their kinematic analysis. I will, therefore, venture to describe such a machine, even at the risk of becoming prolix, believing the apparatus to be more complete than any similar machine which I have seen, and having, after considerable experience, become assured of its usefulness in class work.

The machine which I have in view must be able, in the first place, to compound any two simple harmonic curves for any difference of amplitude period and phase. The compound harmonic of two, or, at the most, three, components is quite complex enough for illustration, and whatever advantage may be gained from further components is more than counterbalanced by additional complexity of apparatus. The wave machine must next be able to set all the compound harmonics in vigorous motion,* thus producing what I should like to call a train of resolute complex waves (not decrepit waves or waves of deficient vitality); it must do this when the components (meeting at the origin initially in any difference of amplitude period or phase) travel with the same or with different velocities in the same direction or in opposite directions. The latter adjustment affords an admirable illustration of the phenomenon of stationary waves, either with fixed or with wandering nodes; the other an equally apt illustration of musical beats for slight differences of periods or slight differences of wave velocity. Döppler's principle is thus put in evidence. Relative to stationary waves the adjustment is to be set either for reflection with or without change of phase in such a way as to clear up the wretched confusion which usually surrounds this subject in elementary physics.

With these possibilities for plane polar-

* Compiled from notes on lectures delivered at Brown University.

* In this respect the photographs fail utterly to suggest the beauty of the machine when in action.

ized waves, the apparatus must next fully represent the corresponding cases for transverse waves in space. It must, therefore, represent all cases of elliptic and of higher (one might say Lissajous) polarization, both as regards the compounding of harmonic curves for all differences of amplitude period and phase of the two components and the corresponding waves resulting for like or different velocities of the components in the same or in opposite directions. It must show that the section of such waves are Lissajous curves for the particular ratio selected, and that these curves are either fixed or in uniform variation as the component wave-lengths, velocities and periods correspond or not.

The machine should, furthermore, be able to compound simple harmonic and circular motion, showing both the complex harmonics and the waves, to which all variety can be given by changes of amplitude, period and phase. Indeed, types of singular complexity are thus obtainable.

Again, the machine should compound two opposite uniform circular motions, differing in period or wave velocity or both, showing the helical harmonic curves as well as the twisted vibratory waves, with special reference to rotary polarization.

Finally, compressional waves must be obtainable, and this with particular reference to their inherently simple harmonic character.

The machine itself must be made not only of easily replaceable parts and sufficiently simple to resist wear and tear, but so fashioned that the functions of the active appurtenances may be understood from mere inspection. As I have carried it out, the machine is built almost entirely of stout tin plate (about ·027″ thick) folded to secure rigidity, with axles of brass tube to facilitate soldering. Anybody in possession of an ordinary roofman's tin bender* for making lap joints, and a little skill in soldering, can make the machine for himself at a trifling cost.

* The edge around which the plate is bent should be rounded. Sharp bends are not wanted.

2. *General Construction.*—Fig. 1 shows the bed plate of the machine with the attached permanent frame work of tin plate; the movable cam axles, AB and CD; the driving wheels or pulley cones, EF, with belt and crank, and the removable back plates, GG vertical and H horizontal.

The framework of the rectangular shape seen is made up of strips of tin plate bent into an elongated C-section, as shown in Figure 7, firmly soldered together and screwed down to the baseboard. The uprights which carry the axles are similarly made, fastened and suitably braced. A very light and open but strong frame is thus obtained which could be used even without the board. The slight yielding which remains is rather an advantage.

The hollow cam axles AB and CD of brass, about 25″ long, parallel and 15″ apart at the same height, are sustained at the ends A and C by pins a and c secured by metal straps of copper at the ends of the uprights. The pins project about 1″ or 2″ into the axles, so that the latter may revolve around them securely. The ends B and D of the cam axles similarly receive the reduced and shouldered axles of the pulley cones E and F, and spring latch pins (one visible at D, and in Fig. 2 at the other figures) fasten the pulleys rigidly to the respective cam axles.

Detached cam axles are shown in Figure 2. The pulleys are grooved so that the speed ratios 4 : 2, 4 : 3, 4 : 4, 4 : 6 may be imparted to the axles by successively moving the belt from front to rear. They are mounted in a horizontal rectangle on four uprights corresponding to axles at the corners, and any tension given to the belt bears longitudinally upon the rectangle without straining framework. The rectangle is wide enough to allow the pulleys to slide laterally when-

ever a cam axle is to be removed. This is done for the front axle, for instance, as follows: Let the metal strap at c be loosened and the pin therein withdrawn; this frees the end C. Now let the spring latch at D be withdrawn and the axle of pulley F slid to the right. This frees the end D. The cam axle may now be withdrawn to be replaced by another on reversing these operations.

3. *Cam axles.*—Each of the cam axles (Figs. 1 and 2) carries 25 eccentrics of thick tin plate, equidistant, about 1″ apart and differing in phase by $\frac{1}{12}$ circumference in Fig. 1, so that in this case there are two complete right-handed turns in each of the helices. The diameter of the rear eccentrics is 4″, with a double swing of 3″; the diameter of the front eccentrics is 3″, with a double swing of 2″, but this series has an advantage of position or leverage, as will presently be seen. A safe minimal margin of ½″ beyond the axle is thus left in each case.

It is usually convenient to keep the rear axle in place. In the room of the front axle, however, the other right-handed helices (Fig. 2), containing respectively 1 or 3 turns to the whole length; another containing one right-hand and one left-hand helix (the eccentrics alternating), and a final one left-handed, with 4″ cams and 3″ throw, corresponding to the rear axle (see Fig. 6), are provided. The two latter are adopted for the illustration of rotary polarization. The three former are a means of obtaining wave-length ratios 1:1, 1:2, 2:3 for all amplitudes, periods and phases on removing the front axle only.

The general purposes of the machine will not require more axles than this, though I have used others to be referred to below.

The eccentrics themselves of the heavy tin plate specified are turned together to a common size on the lathe, and soldered to the axle by aid of a suitable gauge. This need merely be a piece of board of a width corresponding to the distance apart of the cams, and having the phase angle carefully marked on both sides. If the board is perforated normally for the reception of the axle, and cut across axially so as to be removable, the soldering of the cam axles is surprisingly easy. I have also tried other methods with success. The work must be done expeditiously, as prolonged heat warps the cams.

The helices shown in the figure are usually right-handed screws. Since they are stationary, a wave advancing from the operator corresponds to counter-clockwise rotation. This is an apparent disadvantage as compared with left-handed stationary screws, but as the waves in the former case advance from left to right (positively for the observer in front) for clockwise rotation by an operator on the right of the machine the disposition chosen is preferable.

4. *Levers, Riders and Balls.*—To obtain the different types of wave motion from the cams described, long extensible levers of thin brass tube are provided, shown in detail in Fig. 8 (longitudinal dimensions $\frac{1}{8}$, cross dimensions ½), and in place in the remaining figures.

The levers were originally made of heavy guttered tin plate behind and light guttered tin plate in front. Latterly, however, I replaced these by the light extensible 'curtain rods' of very thin brass tube,* consisting of a round tube E snugly telescoping into a wider round tube FF, about 5/16″ in diameter. The first tube E is provided with an axial pin R, 3″ long, carrying a 1/2″ cork ball Q (painted red), representing one of the vibrating particles of the wave. The rod R is not seen in sunshine shadows and is added for this reason. Its end is tipped

* These 'rods' are in the market, each about two feet long, thus admitting of a safe extension to much over three feet. Though made of thin split tube, they fit well. The price is trifling.

with an eyelet (not shown), to actuate other apparatus §§8, 25, 24.

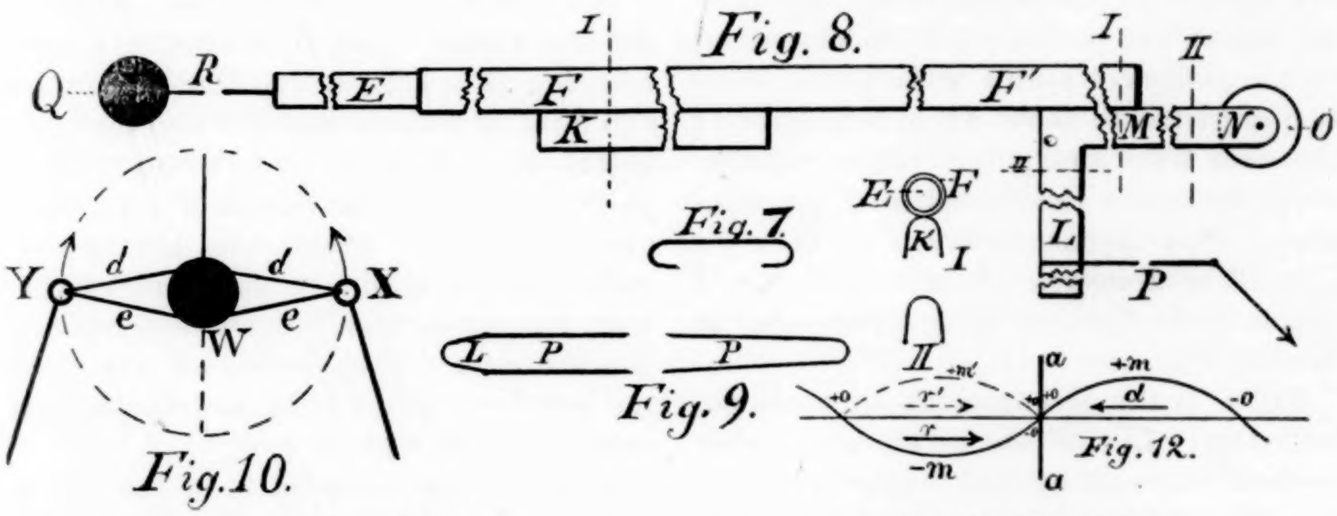
The larger tube FF' carries a U-shaped wide gutter of tin plate K in front, soldered to FF' and adapted to ride on one of the front series of eccentrics. The section through I is seen in the auxiliary figure I, showing all the sectional parts E, F, K in their relative positions. K is $7\frac{1}{2}''$ long and must be carefully placed so as to be adapted to the various types of wave motion. Its position in figure is in the scale specified.

The rear of the tube FF' is fitted with a similar set of gutters of tin plate, M and L, meeting at right angles with their concave sides rearward and downward. This right-angled gutter is adapted to ride on one of the cams of the rear axle, the bearing being on M or L, or both, as the case may be. The section is shown in II. The gutter M terminates in a flat fork, securing and guiding a small vertical roller O, as shown in the figure.

common cross rod (seen at S in Figs. 4 and 5), and they are adjusted as to tension and direction by sliding both ends of the rod S along oblique notched laths of tin plate T on both sides of the machine. The springs themselves appear clearly in Fig. 4, and the riders in different positions in the other figures. The cams in rotating run within the loop of the elastic staple P, and sufficient breadth must be given for clearance. The springs should be as light as practicable to obviate excess of friction on the axle. Steel wire No. 23, wound to a closed helix about 1/2″in diameter and 1/2″ long, is suitable.

The length of the gutter L is 6″, of M to the end of the roller $7\frac{1}{2}''$, and they are soldered to F' to correspond with K.

As regards sure guidance and ease of adjustment, springs placed in the rear of the machine are to be preferred. With less advantage they may be placed between the axles, as was done in my



FIGS. 7 to 10. Details.

FIG. 12. Diagram.

To bind the levers firmly down upon the rear cams, a long staple of thin steel wire (No. 16) P is attached about 5″ below FF'. As shown in plan in Fig. 9, this is about 5″ long and pulled downward to the rear by a helical spring the action of which is indicated by the arrow in Fig. 8. The rear ends of all helical springs are soldered to a

earlier apparatus. Levers heavier at their rear ends are desirable, and in some experiments, if not in all, the machine should be tipped up in front. Waves may then be sent along the axis with considerable velocity.

ACTION OF THE MACHINE.

5. *Method of Compounding.*—Very little

need be said about the action of the machine. It is clear that if the rear ends of the levers are horizontally at rest, but execute S. H. M.* in the vertical by riding nearly parallel to themselves on the rotating cams, the balls Q would execute similarly approximate S. H. M. if the fulcrum K were a common axis for all; but if the fulcrum K, though horizontally at rest also executes S. H. M. in the vertical the motion at Q will be the complex harmonic of which the two stated motions (M and K) determine the components.

Again, if the rear end of the lever is vertically at rest, but executes S. H. M. in the horizontal by leaning against the rotating cams rearward (rider L), the ball Q will do the same provided the slide at K is in a parallel plane; but if the rider K simultaneously executes S. H. M. in the vertical the motion at Q is the complex space harmonic corresponding to the two components stated, etc.

Finally the wave-length ratio is given by the cam axles; period ratios are determined by the pulleys or by the velocities of rotation imparted to those axles, respectively; the cam axle and pulley ratios together then determine the velocities of propagation of the component waves.

6. *Plane Transverse Waves.*—With these explanations the remaining figures will be intelligible.

Fig. 3 is the arrangement for plane polarization. In this case all the levers abut at their rear ends against the vertical plate G, with freedom to slide up and down it in virtue of the rollers O (Fig. 8) when the wave is in motion. Grooves for O are an advantage. Riders K and M are here in action, rider L being kept quite in front of the cams by the plate G. The levers are continually pushed to the rear by the clockwise rotation at the crank, and additionally by the rearward action of the springs.

*Simple harmonic motion.

A notched lath (not shown in the figures), stretching quite across the machine between the axles and swung horizontally and upward on a swivel, is adapted to lifting all the levers at once quite above the front cam so as to permit the easy insertion of another cam axle. Riding on this rail the levers show the simple harmonic due to the rear axle alone.

7. *Transverse Space Waves.*—The machine is adjusted for space waves in Fig. 4. Here the rear ends of the levers are lifted so as to roll in the fore and aft grooves of the horizontal plate H in virtue of the rollers O. Riders M are lifted quite above the cams, while riders KL and the grooves on H now control the motion, the levers being drawn rearward by the spring. The figure shows a circularly polarized wave passing along the particles, being compounded of the horizontal rear wave seen on H and the vertical wave above the front axle. Of course, an inspection of the apparatus is more satisfactory.

In a recent construction I have modified the rear plates G and H, discarding H and adopting G in such a way that it may be slid from its vertical position into the horizontal position (H) by following lateral guides much like the platen of a printing press. The plate now carries all the rear ends of the levers with it, which much facilitates the change from plane to space waves and *vice versa.* The grooves on the plate are preferably much wider and deeper than shown in Figure 4.

In Fig. 5 the machine is in the act of compounding the circular motion of the rear axle with the vertical S. H. M of the front axle. The back plate is wholly removed and the three riders K M L (Fig. 8) now come into play. The figure shows the horizontal S. H. curve, resulting for opposite phases of the vertical components. S. H. structure above the front axle and the circular harmonic arrangement of the rollers in the rear is manifest.

8. *Compressional Space Waves.*—Either of the adjustments, Figs. 4 and 5, is adapted to actuate sound waves, as will be shown below, § 25.

9. *Rotary Polarization.*—Figure 6 shows the apparatus adapted to compound two equal and opposite circular motions, Fig. 10 being a detail relative to it. Both the front and rear series of eccentrics have the same diameter and swing, but there is one turn in front to two in the rear, respectively left and right. The riders are gutters about 4″ long, joined at right angles with the concave sides toward the eccentrics. The extensible levers (tubular as above) are soldered in the prolongation of the bisectrix of the riders, and project from the salient side of the right angle obliquely upward, each passing through a perforation in the horizontal laths of folded tin plate shown at *U U′* and *V V′*. The levers are effectively about 18″ long, and are held down upon the cams by springs * (like the above), one end of each of which engages the lever, while the other is revolubly attached to the axle, between the cams (see Fig. 6). If *U U′* and *V V′* (adjustable) are symmetrically placed with reference to the two effective ends of the levers the upper ends will trace a circle-like figure, corresponding to the circular motion of the lower ends. With the pulleys cross-belted as shown, the pin eyelets *X Y* (3″ long, soldered axially to the upper ends) may then be adjusted to the counter circular motion indicated in Fig. 10.

Two methods of compounding were tried. In the first the ends of two silk threads, Fig. 10, carrying the cork *W* (vibrating particle) between them were fastened to delicate helical springs surrounding the upper ends of the levers. This method constructs the wave very well, but in motion the friction at the eyelets (one of which is often high and the other vertically below it) is apt to be too unequal to keep the particle in the symmetrical position necessary. Better results are obtained by stretching a very thin India rubber band, *dd ee*, between the eyelets, carrying the particle as before. Springs were similarly tested. Parallelogram motion is hardly appreciable here without elaborate construction.

* These springs are seen on the helix in Fig. 2.

The vertical vibration is in this way very well obtained (of course, in semi-amplitude). The horizontal vibration is noticeably curvilinear, seeing that the two motions compounded are not quite uniformly circular. Even in this case, however, the connectors *dd ee* move parallel to themselves.

The helical characters of the wave obtained is well shown in Fig. 6, calling to mind that each ball vibrates normally to the strings by which it is suspended.

The laths *U V* are supported by uprights *Z Z′*, which fit in flat sockets (seen at *J*, in Figs. 4 and 5). With these the whole superstructure of laths, levers and riders is removed from the machine at once in a manner easily suggested. The bed plate then returns to the appearance of Fig. 1.

The method of obtaining similar results in compounding circular motion for the case of Fig. 4 is given below §24. A special cam axle carrying two screws (alternate cams differing 180° in phase) is here needed. If rotary polarization is wanted the wave-lengths of the front and rear axle must differ.

EXPERIMENTS.

10. *Method of Designating Phases.*—Before describing the consecutive experiments to be performed with the machine, it is well to come to an understanding as to the phases in which the two component disturbances meet. These are conveniently determined by the *long axes* of the first eccentrics on each axle, which (axes) may, therefore, be called pointers. Since the waves for clockwise rotation at the crank travel from left to right, along the axle, and since a rise of

the front cams elevates the balls, whereas a rise of the rear cams depresses them, the two component waves will meet in the same phase at the origin when the long axes of the eccentrics there point horizontally away from each other, *i. e.*, when the front pointer is to the front or left of the operator at the crank, and the rear pointer to his right. This is also the null position, or zero of phase (to be marked $+0$), for the first particle of each component wave, *i. e.*, the particle on the left hand (origin) of the *observer* facing the machine in front. Both component harmonic curves and the compound harmonic leave the origin with a descending node, the head of the wave (right semi-wave) being a crest. Absence of phase difference in the component harmonics of the particle at the origin will occur for other cardinal positions of the pointers, viz: front and rear pointers respectively up and down (maxima, marked $+m$), right and left or towards each other (mean position marked -0), and down and up (minima, marked $-m$). These follow each other on like clockwise rotation of both axles over 1, 2 and 3 right angles, while the compound harmonic is shoved forward $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ wave-length. Further rotation of 90° restores the original case.

If the two cam axles contain the same number of turns, the same phase difference obviously corresponds to all particles. Otherwise special consideration is necessary for each case.

Restoring the front and rear cam axles to their original positions (pointers horizontally outward), rotate the rear axle 90°, clockwise, relative to the other. This puts all its particles 90° ahead in phase of the corresponding particles of the front wave. The pointers in their cardinal positions will now be respectively left and down, up and left, right and up, down and right to the operator, etc., for successive additional rotations of 90° each.

TABLE OF PHASE DIFFERENCES. CLOCKWISE ROTATION OF AXLES, POSITIVE. DISPLACEMENTS OF PARTICLES UPWARD AND REARWARD, POSITIVE.

Transverse Plane Waves.	Transverse Space Waves.	Front Axle.	Rear Axle.	Front Axle.	Rear Axle.	Front Axle.	Rear Axle.	Front Axle.	Rear Axle.
Same Phases.		$+0$	$+0$	$+m$	$+m$	-0	-0	$-m$	$-m$
		←	→	↑	↓	→	←	↓	↑
	Front Axle } + 270°, Rear Axle } + 90°	$+0$	$+m$	$+m$	-0	-0	$-m$	$-m$	$+0$
Front Axle } + 90°, Rear Axle } +270°		$+0$	$-m$	$+m$	$+0$	-0	$+m$	$-m$	-0
		←	↑	↑	→	→	↓	↓	←
	Same Phases.	$+0$	$+0$	$+m$	$+m$	-0	-0	$-m$	$-m$
Opposite Phases.		$+0$	-0	$+m$	$-m$	-0	$+0$	$-m$	$+m$
		←	←	↑	↑	→	→	↓	↓
	Front Axle } + 90°, Rear Axle } +270°	$+0$	$-m$	$+m$	$+0$	-0	$+m$	$-m$	-0
Front Axle } + 270°, Rear Axle } + 90°		$+0$	$+m$	$+m$	-0	-0	$-m$	$-m$	$+0$
		←	↓	↑	←	→	↑	↓	→
	Opposite Phases.	$+0$	-0	$+m$	$-m$	-0	$+0$	$-m$	$+m$

Beginning again with pointers away from each other, *i. e.*, with both component, S. H. motions starting at the first particle, let the front axle be rotated clockwise 90° relatively to the other. The pointers in their cardinal positions will now be up and right,

right and down, down and left, left and up, while the particles at the origin run through all phases together. This case corresponds to the preceding for 270°, etc.

All this is evident enough; but it is, nevertheless, advisable to make a diagram of the position of the pointers as here shown, in order instantly to discern the phases in which the initial particles meet in any case. In the table the positions of the pointers are designated by arrows; $+m$ denotes maximum displacement, etc. Further explanation will be given presently.

11. *Space Waves.*—The composition of two simple harmonics at right angles to each other will necessarily require special treatment, for here the rear riders are at right angles to those of the former case, and the S. H. motion of the rear axle is not reversed at the balls. If displacement up and forward from the observer's view be considered positive, then the null position or zero of phase of the particles at the origin corresponds to pointers left for the front axle and up for the rear axle, as seen by the operator. The compound simple harmonic of these components is thus a linear vibration with amplitude $\sqrt{2}$, as regards the equal components, and making an angle of 45° to the horizontal from the observer to the machine. It thus lies in the first quadrant, as seen by the operator at the crank.

Both component S. H. curves leave the origin with a descending node.

Hence, if in the above table we shove the first column of entries one row ahead, *i. e.*, if we begin for no phase difference with the second row and continue in cyclical order, the table will be adapted to the present case. Pointers in opposite directions will thus correspond to counter-clockwise circular motion in the compound wave; pointers in the same direction to clockwise circular motion, as seen by the operator at the crank. The first of these cases will, however, correspond to a right-handed, the second to a left-handed, screw when seen from the origin, since all waves move from left to right.

The table contains an entry relative to the present case. It thus indicates 16 cardinal phase differences for plane and the same number for space waves.

12. *Effective Circles of Reference.*—Finally, a word may be said as to the position of the circles of reference corresponding to the two component S. H. motions. Clearly, the centers of the eccentrics (marked in Fig. 1) determine the amplitude of the S. H. M. In all phases, however, the riders are nearly normally above or else to the rear of these centers by a distance equal to the radius of the eccentric, and, therefore, always in the same kind of reciprocating motion which corresponds to the amplitude and period of the eccentric.

Hence the circle of reference of the vertical S. H. M. is on a vertical diameter and tangent to the highest and lowest positions of the edge of the eccentric on the same side of the axle. The diameter prolonged passes vertically through the cam axis, and its length is twice the throw of the center of eccentric. This circle of reference for the horizontal S. H. M. of the riders (displacement + rearward) is on a horizontal diameter and tangent to the extreme right and left positions of the edge of the eccentric on the same side of the axle.

The amplitude of the vertical vibrations is modified by the lengths given to the extensible levers. If l be the lever length between the axles and l' that beyond the axles, and if a, a' denote the front and rear amplitude at the eccentrics, then the effective amplitude at the particles will be $a(l+l')/l$ and $a'l'/l$, and their ratio

$$\frac{a'}{a}\,\frac{l'}{l+l'}$$

may be varied at pleasure from zero to about 9/8, since l' is the extensible part. Usually the ratio one is desirable.

The amplitudes of the horizontal vibrations do not admit of change without giving useless complexity to the machine. Advantageous lever ratios will be given with the experiments.

I. *Component S. H. Motions Coplanar, of the same Wave-Length.* 13. *Plane Polarization.*—Let cam axles each with two complete turns be selected and the rear plate adjusted to the vertical (Fig. 3). For harmonic curves this implies the same wave-length for the coexisting S. H. motions. With the cams swinging nearly as 2 : 3, and lever ratios $l + l'$ and l' (§ 12) as 3 : 2, the occurrence of no displacement along the line of particles may be looked for in case of opposite phases. This furnishes a method of adjusting the particles at the outset. Practically the condition of no displacement is reached with relatively short levers, say a meter long. When the pointers on the initial cams are away from each other the components meet in the same phase, with the first particle in the axis of motion just about to start vibrating. The double amplitude given by the machine to this compound harmonic (25″ long) of maximum displacement is about 9″. If a beam of parallel rays (sun light) be shot along the axis of the wave, the shadow of the balls on a screen normal to the axis necessarily betrays slight curvature; the double amplitude, instead of being vertical and straight, is concave toward the cams. But the chord deviates from the arc (9″) by less than 1/2″ at the center, and hence with balls 1/2″ in diameter the curvature is negligible to the eye of an observer in front. It must be remembered, however, that curvature is superimposed in all subsequent higher figures.

If the front cam axle be dephased 90° clockwise the amplitude of the compound curve is diminished, the curve remaining sinusoidal but beginning with 1/8 wave-length. If the rear cam axle is also dephased 90° clockwise the compound curve of the first case is restored in the shadow (maximum amplitude), but the phase of the first particle has advanced 1/4 period and the curve itself 1/4 wave-length, etc. I allude to these points because of their value in instruction. (Cf. table, § 10.) By the very make-up of the machine a S. H. curve is seen to result when the phase difference of two particles varies as their distance apart. In drawing such a curve it is simpler to place the circle of reference in the plane of the harmonic; in the machine the circle of reference is preferably placed at right angles to the curve. The addition of two such curves is another S. H. curve of the phase and amplitude directly specified by the machine.

14. *Waves of Constant Amplitude.*—Belting the two equal pulleys and rotating uniformly, waves corresponding to each of the harmonic curves produced in §13 may be sent along the axis of motion. Thus making the phase difference between two particles proportional to their distance apart, and then setting each particle in S. H. M. of a common period and amplitude, is objectively seen to be the realization of simple wave motion. The wave-length being fixed by the apparatus, velocity and period must vary reciprocally.

Particularly striking is the case for opposite phases in the two wave cams. Both component waves are seen travelling in the same direction along the axes with full vigor, whereas the compound effect at the line of particles is permanently nil.

The warped surface of the levers now has a linear directrix at the particle edge and a sinusoidal directrix at the roller edge. It should be noted that the case of maximum amplitude in the compound harmonic presents an approach to a similar linear directrix between the cam axles.

15. *Waves of Varying Amplitude.*—Change of amplitude is given to the levers by draw-

ing out the front tube (§12). Additional change may be obtained by allowing colored balls to ride on the levers. In case of equal periods the result is chiefly interesting when the amplitude varies from particle to particle. A linear variation is well represented by a plane wave oblique to the direction of the axles, and in action is very striking.

The more important wave with an exponentially varying amplitude is only given when the axis of motion is along the corresponding exponential curve horizontally, but the effect to an observer at a little distance in front is none the less good.

II. *Preceding Case (I) with Additional Velocity Superimposed on Either Wave Train.* 16. *Beats.*—If the component waves are transmitted in like periods or velocities* and amplitudes, the compound wave is transmitted unchanged in form; but if any of these quantities vary, the compound wave continually changes form. With the apparatus as here adjusted the last case is readily realized by sending on one wave faster than the other. For instance, if the component wave velocities be as 3 : 4 (rear wave of greater speed), then in 4 complete turns at the crank the original wave will be reproduced, while all intermediate phase differences between corresponding particles are passed continuously in turn. All pairs of cams are undergoing like continuous change of phase.

The shadow picture of this case (sunlight) shows a line elongating to maximum displacement and then contracting to a point in S. H. M. The slow change at maximum elongation is in strong contrast to the rapid change of length on passing through the position of equilibrium. Similarly in §14 the speed ratio must be carefully adjusted if the linear compound wave is to persist.

* In the present special case variation of one implies the other; in the sequel, period and velocity must be carefully distinguished.

The wave corresponding to this present experiment is an excellent example of an infinite beating wave train, two wave-lengths of which are accessible at a given place. The beats are due to a difference of wave velocity and frequency together. Though the two cases are usually generically different, the gross effect is here coincident. As a luxury a cam axle containing a small fraction of a wave-length more than two complete wave-lengths might be supplied. This would then show beats due to difference of wave velocity for the same period or (with the proper pulley) beats due to difference of period for the same wave velocity. The specific difference is this, that, whereas in one case (equal component wave-lengths) the compound harmonic is at every instant (for all pulley ratios) sinusoidal, in the other case (slightly different component wave-lengths) it is at no instant strictly so. The latter adjustment thus admits of beats either when the component periods alone or the component wave velocities alone are not the same. In the former both necessarily change together.

17. *Döppler's Principle.*—If the beats are obtained by a difference of wave velocity the faster wave may be treated as having an additional linear velocity *virtually* impressed upon it in the direction of motion from without. Its interference with the wave not so affected is then an illustration of Döppler's principle.

III. *Preceding Cases (I and II) with the Velocity of Either Wave Train Reversed.* 18. *Equal Velocities. Stationary Waves.*—If one of the component waves be passed along the axis positively and the other in a negative direction, *i. e.*, if one axle be rotated clockwise and the other counter clockwise by cross-belting equal pulleys, the compound wave is of the stationary type, since amplitudes were made effectively equal and periods are necessarily equal. The effect on the machine is striking, since the nodes are

here indicated by stationary particles half a wave-length apart, while the antinodes vibrate 9″. In all positions the form of the compound harmonic curve is at all times a simple sinusoid, but its mode of motion as compared with the same curve while both components are direct is totally different.

Again, if the first pair of cams are in the same null phase (pointers away from each other) the first particle is a node, succeeded by four other nodes one-half wave-length apart, and the wave is initially at maximum amplitude. If the first pair of cams are in opposite null phases (± 0) the initial harmonic curve is linear, the first of four nodes one-fourth wave-length ahead, etc.

Reflection.—The first of these cases corresponds to reflection from a denser, the second to reflection from a rarer, medium at the origin. It is worth while to examine the interpretation of both cases* for transverse waves first, and thereafter, §26, to similarly treat longitudinal waves.

If the direction of a wave is reversed, particles without displacement (± 0) are changed half a period in phase (becoming ∓ 0); particles at maxima or minima ($\pm m$) are not changed in phase at all, while the phases of intermediate particles are changed in the corresponding harmonic ratio. This may be tested at once by supposing the full wave, Fig. 12, to advance first in direction d, thereafter in direction r, when the particles vibrating in the line aa will respectively rise and fall, thus passing between opposed phases; etc.

The transverse wave advances through a given medium at rest, with the zero of displacement (± 0) in the wave front, so understood. Hence to reverse the direction of a wave is to reverse the phase of the wave front.

If the transverse wave encounters a denser medium this implies that the particles therein situated are capable of *reacting with forces in excess* of those corresponding to the original medium. If the medium is quite impermeable (as when the wave on an elastic cord meets the peg) the reaction is exactly equal and opposite to the action. Thus if a wave advances toward the dense medium with a crest or group of pulls upward the medium itself must at every instant react with equal pulls downward. This reaction, which in its succession is bound to be rythmic like the impinging wave, is the impulse of the reflected wave, which must all be returned into the first medium (*i. e.*, be reversed in direction) if none can enter the new medium.

Now, let the particle in the wall aa (Fig. 12) be in the zero of phase ($+0$). The direct wave advancing, as shown by d, is in the act of increasing the displacement. It is developing an increasing pull up. The reflected wave (prolonged) r is simultaneously in the act of developing the counter pull down; it is, in like degree, tending to decrease displacement: but, though the phases impressed by the direct and reflected wave are thus initially quite opposite, both waves d and r momentarily constitute contiguous parts of the same harmonic curve. If this curve separates at aa, with the parts d and r moving with equal velocity in opposite directions the condition for action equilibrated by reaction at aa is maintained throughout all time.

The explanation is essentially the same if the reaction is not complete (permeable dense medium). In this case the amplitude of r will be smaller, other conditions remaining the same.

Hence in the machine the pointers are to be set for equal and opposite displacements at the origin, beginning with the null phases of each component wave—the case of Fig. 12, where if d and r were moving in the same direction, or the pulleys not cross-belted, the two components would meet in the same place.

*Waves as here considered are essentially steady.

On the other hand, if the direct wave meets a rarer medium at *aa* the reaction is less than that of the original medium. The pull up developed by the wave *d* in Fig. 12 is not resisted by an excessive pull down as before. The reaction (which from its rhythmic character develops the reflected wave) is an additional pull up, such as would correspond to a wave *r′* in Fig. 12. Both waves *r′* and *d* are in the same phase as regards their effect on the initial particle at *aa*, but they differ in direction of motion. In other words, the direct wave *d* and the reflected wave prolonged *r′*, are not initially contiguous parts of one and the same wave, meeting without displacement at the wall. Half a wave-length is necessarily lost at the inception.

This determines the method of setting the pointers of the machine for equal displacements of the same sign at the origin, beginning with opposite null displacements; for the two waves *d* and *r′* if traveling in the same direction (cf. Fig. 12) would then annul each other.

Summarizing; the reflected wave from a denser plane boundary normal to the axis is obtained from the incident wave by *two* rotations of 180° each; one around the axis of motion, the other around the trace of the wave plane on the plane of the obstacle; these correspond respectively to the substitution of reaction for action, and of an opposed direction for the given direction of motion—two reasons for change of phase. The wave advancing *crest on* (crest foremost) returns *trough on* and *vice versa*.

The reflected wave from a rarer plane boundary is obtained from the incident wave by a *single* rotation around the trace in question. The only reason for change of phase is change of direction. The wave advancing crest on returns crest on, and the trough returns a trough. Cf. §26.

If the component amplitudes are made unequal the nodes show a correspondingly slight vibration, the case corresponding to a medium at the origin neither absolutely impermeable nor absolutely rare.

19. *Wandering Nodes.*—If with equal amplitudes the velocities or periods of the components be unequal in value and opposite in sign the case becomes one of stationary waves with continually drifting nodes. Thus if the 3 : 4 pulley be cross-belted four turns of the rear or faster cam axle will continuously move the node half a wave-length onward. The stationary character is, nevertheless, very thoroughly retained.

In the extreme and transitional case where the velocity of one wave is zero and the other of any value a single turn at the crank moves the nodes half a wave-length and thus reproduces the original curve.

IV. *Component S. H. Motions at Right Angles to Each Other of the Same Amplitude and Wave-Length.* 20. *Elliptic Polarization.*—Using cam axles with two waves each and adjusting rear ends of levers (Fig. 4), while the vertical riders *L* engage the cams, two simple harmonic curves are available to be compounded at the particles. This is usually an elliptic helix. It is advisable to tip the machine up in front with the object both of relieving the work of the springs and of exhibiting the wave symmetrically with reference to a horizontal plane through the axis.

In order that circular polarization may be obtained, the amplitudes of the particles must be equal. The rear cams contribute their full swing independent of the levers. The fore cams enter with an amplitude which may be more than doubled, though the fulcrum of the levers is now at the rollers. Thus the levers are to be shortened from 1 meter to about 70 cm. to obtain circular paths 3″ in diameter for the single particles. Shorter levers would give oblate ellipses, larger levers prolate ellipses, for their central figures. Cf. §36.

The two S. H. motions will meet and

exist throughout in the same phase if the pointer on the rear eccentric is 90° ahead of the other, supposing, in accordance with the above table, that directions upward and rearward are positive. The zero of phase thus begins with front pointer left and rear pointer up. If the pointers are parallel and in the same direction the front harmonic is 90° in phase ahead of the other. The compound harmonic is circularly polarized and the corresponding wave advances with counter-clockwise rotation if seen in the direction of advance, *i. e.*, from left to right to the observer in front. Dephasing the front axle 90° farther (180° advance) produces plane polarization at 135° to the horizontal; 90° farther (total advance 270°) finally a circularly polarized harmonic curve with a wave advancing in the direction of the components with clockwise rotation, as seen from the origin. All intermediate cases are elliptically polarized with intermediate rotation.

The sunshine picture on a screen normal to the axis with rays parallel thereto is in general an ellipse with the appropriate rotation discernible with remarkable clearness.

V. Preceding Case (IV) with Component Velocities or Periods Unequal. 21.—If the component waves do not advance with the same velocity (necessarily implying difference of period in the present case) the difference of phase of the first pairs of cams is continually changing, and the phase difference of all succeeding cams is changed in like measure. Hence the compound wave passes continuously through all the different harmonic curves in turn. If the belt be placed on the 3 : 4 pulleys four turns of the rear axle restores the original form through all intermediate forms, beginning, for instance, with plane polarization at 45°, passing through circular clockwise polarization (seen from the origin) into plane polarization at 135°; then back with counter-clockwise rotation into plane polarization at 45°.

The sunshine shadow of this case is identical with the Lissajous figures from two tuning forks slightly different in pitch but of the same amplitude. The directions of rotation are particularly evident, enhancing the instructivenes of the figure.

VI. Preceding Case (IV.) with Either Component Velocity Reversed. 22.—If with equal amplitudes and wave-lengths the component waves travel in opposite directions (pulleys cross-belted) the compound wave is a peculiar form of stationary wave in which the form of vibration of all particles is sustained, but in which the motion of each particle differs uniformly in regard to the phase difference of its components, *i. e.*, in ellipticity, from its neighbors. Thus a group of particles a wave-length apart are plane polarized at 45°; particles midway between plane polarized at 135°; particles midway between both groups circularly polarized with alternately opposite rotations and all other particles correspondingly elliptically polarized. The envelope of the harmonic curve would be given by a thin tube 3″ in diameter, compressed at equal distances by a pair of shears to lines at right angles to each other, but alternately in the same direction. The case is thus thoroughly different from the case of unequal velocities in the same direction, where all the particles under observation are instantaneously in the same ellipticity.

23. *Velocities Reversed and Unequal.*—If the two component waves of the same wave-length have unequal velocities (and periods) of opposite sign the plane polarized groups wander. Thus if the 3 : 4 pulleys be taken 4 turns of the rear crank reproduces the original wave. The transitional case is again that in which one cam axle is stationary (wave velocity zero) while the other rotates. A single turn reproduces the original figure.

VII. *Preceding Case (IV.) Adjusted for Rotary Polarization.* 24.—If a special axle be provided with the cams alternately in opposite phase to the normal occurrence, but otherwise equal in amplitude and wave-length, and if the corresponding balls be painted red and white, the two circularly polarized waves occur simultaneously. Similarly, the two plane polarizations at 45° and at 135° occur simultaneously; etc. The former case is interesting in relation to rotary polarization, as will be more fully indicated below; for the two circular motions may be compounded by the device shown in Fig. 10, and a harmonic curve plane polarized in the vertical or the corresponding wave will result (cf. §40 *et seq.*).

To obtain rotation of the plane of polarization by this method the alternate cams on both the front and rear axle would have to be set for some other wave-length in the manner stated.

(vertical) axles of which are at the angles of the cranks, as far apart as the cams, and all arranged along a straight line parallel to the cam axle. The short shanks of the bell cranks now carry a series of $\frac{1}{2}''$ balls, which, under present conditions, must, therefore, vibrate nearly parallel to the cam axles, *i. e.*, longitudinally right and left in the line of advance of the wave, whereas the thrust of the levers* is harmonically to and fro.

In practice the long shanks are open sectors of wire, swung so as to clear each other's axles.

In this way the alternate compression and rarefactions of such a wave are remarkably well shown (cf. Fig. 11), the sinuosity in the line of particles being negligible at least to the observer in front. The balls approach each other to about $5/8''$ between centers (all but contact in the compressional phases), while they sepa-

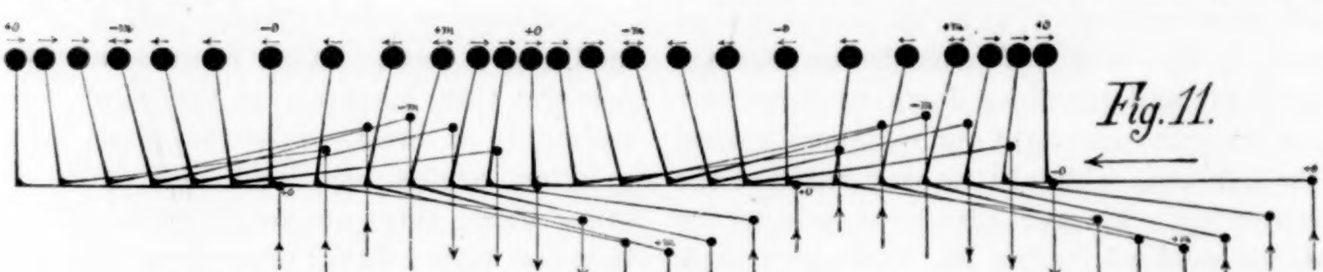


FIG. 11. Adjustment for compressional waves, seen from above. Diagram. Wave advances from left to right to an observer in front. Lever displacements positive rearward. Ball displacements necessarily reversed.

VIII. *Waves of Compression and Refraction.* 25. *Longitudinal Vibration.*—With the apparatus arranged as in Fig. 4, let the levers all be raised at the front ends, so as quite to disengage them from the front cam axle. This being, therefore, out of action, the rear or horizontal harmonic of $3''$ double amplitude forward and rearward thrust is alone in play, as shown in plan by the parallel lines normal to the axis in Fig. 11. Now, let the ball ends of the levers (eylets) engage the long shanks ($6''$) of a series of horizontal, *right-angled* bell cranks, the equidistant

rate to more than about $1\frac{3}{8}''$ in the rarefied phases.

The great advantage of an arrangement of this kind from the kinetic point of view is the direct evidence furnished that each ball in the first instance is actually in S. H. M., and that the phase difference between balls is proportional to their distance

* The reader should remember that Fig. 11 is seen from above and that direction rearward in the transverse harmonic (down in figure) is positive wave velocity left to right in the machine, becomes right to left in figure. Balls in front reverse their positive motion.

apart, while the compression and rarefaction of such a wave is an incidental phenomenon. This essential structural character of the acoustic wave is not generally enough insisted on.

In the same way any of the above or the following complex plane polarized waves may be converted into compressional waves by using vertical bell cranks (horizontal axes). For the case of stationary waves this would be of some interest, but I have not carried out the construction. Since small displacements are wanted, the engagement of levers should be located between the axles.

26. *Reflection.*—There is bound to be confusion if the reflection of a compressional wave from a denser or a rarer medium is to be explained without reference to the elementary S. H. M. of the particles of such a wave. Relatively to § 12 and Fig. 12 it follows that the explanation there given is at once applicable to S. H. M. in sound waves, the only difference being that for pulls up and reactions down we have now pulls toward the right and reactions toward the left, etc., which in no way modifies the reasoning. A wave advancing toward the dense medium 'crest on' returns 'trough on'; advancing toward the rare medium with a crest returns a crest. Let no one suppose, however, that crest and trough mean compression and rarefaction. For it is just here that a slough of despond awaits the incautious interpreter. A glance at Fig. 11, where the oscillations of particles have all been marked, shows that *the centers of compression and of rarefaction are without simple harmonic displacement (phases ± 0); that the maxima and minima of displacement ($\pm m$) lie in air of normal density.* If the wave is to advance with particles in the wave front in the zero of displacement it must advance the center of a compression or the center of a rarefaction sharply into normal air. Thus, the particles on one side only of the balls marked ± 0 in Fig. 11 must indicate the status of an advancing sound wave; moreover, if the former begins a crest, the latter (particles on the other side of ± 0) begin a trough, and *vice versa.*

In this structural fact lies the gist of the true explanation: If a compression meets a denser medium it is reflected as a compression surely enough, but the two compressions are not the same. The symmetrical half of the incident compression is returned. The two halves lie on opposite sides of no displacement, and are the contiguous halves of crest and trough required by Fig. 12. So the two symmetrical halves of a rarefaction become incident and reflected wave, initially meeting the plane of reflection as contiguous trough and crest. In both cases crest returns trough, and trough crest, even though two compressions or two rarefactions are in question.

If reflection takes place from a rarer medium a compression returns a rarefaction; this, however, is the rarefaction ending in a crest, while the given compression begins one, and *vice versa.* In other words, there are two crests advancing in opposite directions; or crest returns crest, even though a half wave-length is initially lost and though a compression returns a rarefaction.

The agreement with §12 is thus complete and the whole explanation logically simple throughout.

IX. *Component Simple Harmonics Coplanar, with Wave-Length Ratio, 1:2. Harmonic Curves.* 27.—Replacing the front cam axle by another containing a single wave-length and 2″ double amplitude, the plane compound harmonics for period ratio 1:2, for the same or different amplitudes and for any difference of phase, may be exhibited in succession. The cams are exchanged by lifting all the levers above the front axle, by aid of the notched swivelled cross-lath

(when an opportunity to show the rear harmonic *alone* is afforded as the levers now ride on a common fixed axle in front), after which the single wave axle is easily inserted and the levers dropped down upon it by lowering the cross-lath.

Reference to the scheme of phases compiled in §10 shows that 16 generically distinct compound harmonics with an indefinite number of intermediate curves are obtainable. The variation is further enhanced by changing the component amplitudes by drawing out the levers. Among forms for equal amplitude the symmetric types are distinctive. They are obtained concave upward more or less *W*-shaped for components meeting at the origin both at maximum displacement ($+m$), and more or less *M*-shaped when both components meet at the origin at minimum displacement ($-m$). Similarly symmetrical forms are seen when the components at the origin are in opposite phases, viz., *V*-shaped when the front harmonic is at $+m$ and the rear harmonic at $-m$, and Λ-shaped when the front harmonic is at $-m$ and the rear at $+m$.

28. *Waves.* If these curves are to be transmitted in a compound wave which does not change its form each component must travel equally fast. Hence the rear axle with two wave-lengths must be rotated twice as fast as the front axle with one wave-length (pulleys 2 : 1) The periods are now also in the ratio of 1 : 2. Thus it appears, that it takes two rotations of the rear axle to exhibit the complete wave, or beginning with a symmetric type, for instance, the *W* and Λ curve together make a single harmonic curve; whereas the *M* and *V* curve make another, in relation to waves; etc., for non-symmetrical forms. The character of the wave is markedly progressive, each little kink as well as large elevations or depressions running along the axis in turn.

Referring again to the above table §10, the present succession of phases is a march along a *diagonal* passing from left to right downward across the diagram.

29. *Case IX. with Component Velocities Unequal.*—If the component waves are transmitted unequally fast the compound wave continually changes form. Thus, if the 2 : 3 pulleys be used, it takes 3 turns of the rear axle to reproduce the original form ; in 3 : 4 pulleys, four turns ; in 1 : 1 pulleys, but a single turn. In the last instance the waves produced are much like stationary waves, with two nodes at the ends if the components meet at the origin in opposite phases, and one node in the middle if they meet in the same phase, phase difference being maintained constant at each cam. The table, §10, shows that the passage is now from left to right across the diagram, along a single row.

If one axle alone rotates a single turn again reproduces the original form, but the wave has now a progressive character, which is an inversion of the result in §28. In other words, the *W* and *V* types or the *M* and Λ types of curve are successive. In the table of phases, §10, the present succession for any single cam is given by a column passed from top to bottom.

30. *Case IX. with One Component Velocity Reversed.*—If the axles rotate with equal velocity in opposite directions the wave presents the succession of forms of the first (normal) case, but its character is now non-progressive, each particle retaining its peculiar form of vibration, which differs regularly from that of neighboring particles. But half the full wave is represented at once. No particle is permanently at rest and the stationary character is less pronounced than for the case in §29 with equal pulleys. Particles at the end of the curve in view are in like figures of vibration. In the above table, §10, the passage for any single pair of cams is now diagonally across the diagram, but from right to left, downward.

X. *Components Simple Harmonics at Right Angles to Each Other, with Wave-Length Ratio, 1:2. Transverse Space Wave.* 31. *Harmonic Curves.*—With the preceding cam axles, let the rear ends of the leaves be lifted upon the horizontal back plate and adjusted for the same component amplitude (Fig. 4).

Space waves of this and the following kind may be conveniently termed Lissajous waves, since their sunshine shadow on a screen normal to the axis of motion is always the appropriate Lissajous figure. Starting the waves with the initial eccentrics towards each other, the harmonic curve has a meandering space form, characterized, however, by its sunshine shadow, which is the specific bow-shaped 1:2 Lissajous, concave toward the cams. Dephasing the rear axle +90° produces the symmetrical 8-shaped figure; +90° farther the bow-shape again, this time, however, convex toward the axles of the cams; +90° farther returns the 8-shape described in a direction opposite to the preceding. The intermediate cases are assymmetrical 8's, but not well given unless the balls are small enough.

The harmonic curves themselves present no marked complexity. Seen from above they contain two wave-lengths; seen from the front but one wave, each in the appropriate phase at the origin. This gives a very clear analysis of the occurrences. The wave envelope in the bow-shaped cases is a gutter.

32. *Waves.*—The waves corresponding to the above space harmonics are instructive. If the figure of the compound wave is to be preserved, *i. e.*, if its shadow Lissajous is to remain fixed, both component waves must advance with rigorously the same velocity. This implies double rotation (double frequency) for the rear waves of shorter wavelength. The direction of rotation in the shadow is particularly well marked. For initially opposite or for like phases at the origin the figure is alike 8-shaped, but when horizontal pointers on the front axle correspond to down on the rear or up on the rear the rotation is clockwise or counter-clockwise respectively in its upper half; etc.

33. *Case X. with Component Velocities Unequal.*—If the velocities of the component waves are unequal, but of the same sign (pulley 2:3, for instance), the compound wave continually changes form, as is best shown by the sunshine shadow. This is identical with the Lissajous curve for two tuning forks of the same amplitude, but with period ratios slightly different from 1:2. If the speeds of the two axles are equal (pulleys 1:1) a single rotation of the crank produces all the Lissajous between two occurrences of the same figure.

If the component periods are equal, but of opposite sign, stationary wave conditions appear for this case. Particles at the ends of the compound wave oscillate in any fixed Lissajous; the intermediate particle has the inverse figure. In general the permanent vibration figures vary proportionally to the distance apart of the particles. The sunshine figure is reproduced for 1/2 rotation at the crank. One may note the contrast that, whereas the particles themselves vibrate in the elliptical Lissajous series, the sunshine shadow produces the 2:1 series.

If the component periods are unequal and opposite in sign the figures drift as above. The transitional case is given when but one axle rotates.

XI. *Component S. H. Motions Coplanar with Wave-Length Ratio, 2:3.* 34. *Plane Harmonics and Waves.*—The front cam axle is replaced by one containing 3 wave-lengths, with adjustments as above (Fig. 3). The curves of this series are more complex than the preceding, and if the dephasing be effected in steps of 90° each, 16 marked forms of curves may be exhibited. Among these the symmetrical types are

best adapted for recognition. They correspond respectively to like phases at the origin with maximum or miminum displacement of both components (*W*- and *M*-shaped forms), or to opposite phases at the origin with maximum and minimum, minimum and maximum displacements of the components (*V*- and *Λ*-shaped forms).

If the component waves are to advance with the same velocity the rear cam axle rotates twice while the fore axle rotates thrice, thus establishing a period ratio of 3 : 2. Hence each wave contains two of the specified harmonic curves in succession, or only one-half of it is seen at once. The progressive character of these waves as they dash along is singularly pronounced.

If the axles rotate equally fast in the same direction the wave assumes a stationary type, with one node at the middle of the component harmonics meeting at the origin in the same phase. If the latter meet at the origin in opposite phases, nodes occur at the two ends with marked vibration for intermediate parts of the compound wave. If the cam axles rotate equally fast, but in opposite directions, the compound wave shows 6 nodes if the components meet in opposite phases at the origin, and 5 nodes under other conditions.

Finally, if the wave velocities are equal, but opposite in sign, there is permanence in the vibration form of each particle, with difference of phase between them, but no nodes.

XII. *Component Simple Harmonics at Right Angles to Each Other, with Wave-Length Ratio 2:3*. 35. *Transverse Space Waves.*—The results are similar to the above cases, only more complex. The sunshine shadow on the normal screen shows the 2 : 3 Lissajous figure in permanent form if the axes are rotated at angular velocities of 3 : 2. The component waves are then transmitted with equal velocity and the period ratio becomes 2: 3. If the component waves are transmitted with other velocities the compound wave continually changes form, as does also the Lissajous shadow curve. The rotation within it is here again exhibited as to direction, etc., with remarkable clearness. To obtain steady results for this case the balls must be small and the ratio workmanship of the machine accurate, otherwise the inconmensurable cases supervene. Experiments are made as above.

XIII. *Component Harmonics Circular and Vertically Simple Harmonic of any Wave-Length Ratio.* 36. *Harmonic Curves for Equal Component Wave-Lengths.*—The present curves are interesting, inasmuch as they present an intermediate stage between the above cases of S. H. composition and the next cases relating to the composition of circular motions. The wave machine is put into adjustment, as shown in Fig. 5, with cam axles and pulley ratios 1: 1. The machine is tipped up in front.

Inasmuch as the S. H. M. of the front axle interferes with the vertical component of the circular motion of the rear axle, the phase difference is best specified in terms of these coplanar vibrations. For like phases, therefore, the Lissajous figure of the compound curve is a tall vertical ellipse, say 9″ high and 3″ broad. Advancing the front phase +90° inclines this ellipse to the rear, shrinking it throughout. Advancing the front axle +90° farther produces the simple harmonic curve in the horizontal with a double amplitude of 3″. The further advance of the front phase of +90° expands the Lissajous figure into an oblique ellipse inclining to the front, etc.

37. *Waves.*—The rotation in the waves is always clockwise for a clockwise circular component. In this and other respects (pronounced prolateness combined with horizontal plane polarization) they differ from §20.

38. *Waves and Curves for Other Component Wave-Lengths.*—On replacing the front cam axle with one of one or three waves to the

two of the rear axle, peculiar apparently beknotted wave forms are obtained, well adapted to give a notion of the complexity resulting from simple compounding; but it is needless to refer to them further.

XIV. *Component Harmonics Both Circular, of any Wave-Length Ratio and Opposite in Direction.* 39. *Remarks on the Machine.*—After the description of the machine and the remarks already made in the successive paragraphs above, it is not necessary to enter at length into a consideration of the present experiments. As to matters of adjustment in Fig. 6, I may note that the common horizontal locus of the centers of the approximate circles described by the free ends of the levers (they are really curves of the 6th degree), and the respective cam axles, must be equidistant from the perforated cross laths, *U* and *V*. In the given apparatus the effective lever length is about 18″. In this case the lever ends describe curves which do not differ more than 1/8″ from circular circumference, a departure not discernible with 1/2″ balls. Nevertheless, the angular velocity in the quasi-circles is not uniform, a circumstance which from symmetry is without bearing on the vertical compound vibrations, but becomes more marked in proportion as the vibration is twisted around into the horizontal. The latter, therefore, appears somewhat convex downward unless very long levers are chosen. The adjustment in § 24, where the circles are nearly quite perfect, is thus in many respects to be preferred, though the levers are necessarily farther apart and the lever ends incapable of resisting much tension. There is inconvenience, however, in constructing special pairs of front and rear cam axles.

To find whether the circles at the lever ends have a common cylindric envelope the cam axles should be rotated in like direction. Coincident ends should then remain nearly coincident throughout. The cross laths, *U* and *V*, are adjustable with this test in view.

40. *Rotary Polarization. Equal Component Wave-Lengths.*—Let the front cam axle be a left-handed, the rear axle a right-handed, screw (Fig. 6). Let them be equal in wave-length and amplitude. Then the component harmonics (loci of the lever ends or eyelets) will be respectively right and left circular helices, otherwise equal. The vibration lines of the particles, *W*, in Fig. 10, will all be coplanar, the plane being parallel to the cam axles at any angle to the horizontal depending on the phase difference of the initial cams. The compound harmonic, or longitudinal arrangement of the particles in the plane stated, is a simple harmonic, curve whose amplitude is the common diameter of the component circular harmonics.

This case has already been referred to in §24 and there exemplified. The compound curve, as constructed by the machine, is on a scale of one-half.

If the cam axles are rotated with the same velocity, opposite in direction (cross-belt), the corresponding plane-wave will result, unchanged in obliquity. One may note in passing that, whereas, in all the above compounding, plane-waves were obtainable in one or two special altitudes merely, they may now be obtained in all altitudes.

41. If the axles are rotated with unequal velocities, components of equal wave-length differ in period and velocity. The plane of the compound wave will, therefore, rotate about the axis of the component circles. Hence, if the oscillation of the first particle be put back into the same line after each oscillation (in general, continuously), *i. e.*, if oscillation is continually *supplied* at the origin in this line, the amount of rotation resulting will be proportional to the distances between particles. The rotary polarization so produced is due to a

difference both in the *period and the velocity* of the component circular waves of like wave-lengths.

42. *Unequal Component Wave-Lengths.*—With the front and rear cam axles still respectively left and right, if more turns be put on one than on the other, the harmonic curves will become helical. In other words, the compound of two plane simple harmonic curves of the same wave-length ratio and phase difference at the origin will now be inscribed on a regular helix. If the axles be rotated with the same angular velocity in opposite directions the component harmonics have the same period, but differ in velocity. The vibration lines in the compound wave remain fixed for each particle, but their directions differ in altitude proportionally to their distance apart. The rotary polarization so obtained is due to a difference in the *velocities* of the circular components. The helix may be rotated as a whole by dephasing the initial particles.

43. If the axles are turned with unequal velocities the helical compound wave must rotate as a whole about the common axis of the component circles, in consequence of the continuous and like dephasing at all cam pairs. Rotary polarization is again due both to difference of velocity and of period, as in § 41. If, however, the period of rotation at the cam axles is proportional to the wave-lengths of the helices the velocities of the components will be the same and the continuous rotation occurring due merely to difference in the periods of the components. Hence, if the oscillation in the first particle of the compound wave is always supplied parallel to a given line the rotary polarization obtained will be due simply to the difference in the *periods* of the components.

44. *Right-Handed Circular Component Harmonics.*—The same amount of rotation as in the last cases will be obtained when the wave-length of one of two equal right and left cam axles is increased and that of the other decreased by half the stated increase of the single axle in § 42. It will even be obtained when both cam axles are right-handed screws or both left-handed screws, alike in all respects but differing in phase by 180°, subject as before to counter rotation (cross-belted). But, whereas the rotary polarization in the preceding case, § 42, is due solely to normal advance of the circular waves, it is now due to the independent counter rotations impressed by outside agency. The two right-hand helices specified, being opposite in phase, constitute a series of stresses in equilibrium and produce no displacement.

If the cam axles of equal wave-lengths rotate with the same velocity the compound wave is a helix, but with each of its particles in the same phase. The neutral position is thus a line of balls in the common axis encircled by the lever ends, and this may be used as a test on the adjustment. Each particle persists in its line of vibration, and their locus is a helix which expands and contracts in diameter rhythmically.

45. If the two axles rotate unequally swiftly the component circular waves advance unequally swiftly and the line of vibration of each particle or the contractile helix as a whole rotates around the common axis.

46. Finally, in two right-handed cam axles of equal amplitude, but different wave-length, the resultant harmonic curve will be the compound of corresponding plane harmonics, but inscribed on the corresponding helix. For rotations of the same angular velocity (equal periods) the helical wave will not rotate as a whole. For unequal periods it will so rotate.

Some of these cases are more important than others. Their application is a question of optics.

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THE WORK OF THE U. S. FISH COMMISSION.

THE report of the U. S. Commissioner of Fish and Fisheries for the year ending June 30, 1898, shows an increase in the propagation and distribution of food-fishes of about 40 per cent. over the work of any previous year.

The number of adult and yearling fishes, fry and eggs distributed in public and private waters or transferred to the State authorities was about 857,000,000, of which the largest number represented important commercial species, like the shad, cod, whitefish and salmon. There were thirty-three hatching stations and sub-stations in use, the steamer *Fish Hawk* being also utilized for shad-hatching in Albemarle Sound and the Delaware River.

The extension of the salmon-hatching work on the Pacific coast was especially gratifying, as the enormous annual drain on the salmon streams of that region makes it very important that the supply should be kept up by artificial means. At the sub-station situated on Battle Creek, a tributary of the Sacramento River, the largest collection of the salmon egg (48,000,000) in the history of fish-culture was made in the fall of 1897.

Particular attention was also paid to the hatching of young lobsters, owing to the steady decline in the lobster fishery, and as a result of these efforts no less than 95,000,000 fry were turned loose.

There is little doubt but that the future success of the lobster industry depends on the possibility of artificial propagation, and the same may be said of the salmon fisheries of the Pacific coast. What may be hoped for is shown in the steady increase of shad in the eastern United States.

In 1880 the catch was only about 18,000,000 pounds, and the catch steadily decreased until 1885, when the results of artificial propagation became observable. By 1888 the catch had doubled, and in 1896, the last year for which there are accurate data, the catch amounted to 50,866,368 pounds, with a market value of $1,656,711, the value of the increased catch for that year alone being something like $800,000 in excess of the total cost of all shad propagation up to that date. Extended tables show the output of the different hatcheries and the details of the distribution of the eggs and fry of the various species.

The Division of Inquiry respecting food-fishes has made various investigations regarding the oyster, including a survey of the oyster grounds of Louisiana and a re-examination of the much-vexed question as to the origin of the color of green oysters. In regard to this the report states that in the United States it has been repeatedly demonstrated by the Commission that the green color is due to vegetable matter which serves as food, and that there is no impairment of the edible qualities of the oyster. The reason for the color of the 'red oysters' noted during the season of 1896–97 is unknown, as no opportunity was given to investigate the problem, but it is suggested that it may be due to the presence of the infusorian *Peridinium*.

In view of the scarcity of mackerel, which has extended over a longer period than ever before in the history of this fishery, special study has been given to the embryology, natural spawning and artificial propagation of this species. Its practical propagation is still an unsolved problem, and it is noted that under existing conditions the number of eggs obtainable is too small to produce any appreciable effect, while suggestions are given for enlisting the aid of the fishermen. The principal work of the Division of Statistics has consisted of canvasses of the more important fisheries of certain of the New England and Middle Atlantic States and of the Great Lakes, the information thus collected being made immediately available by the publication of

single-sheet bulletins. It is proposed to continue the issue of these from time to time whenever there is information of special interest. Attention is called to the fishery resources of the Yukon River, which so far have been utilized only by the Indians for their immediate needs, but which it is believed may afford a food supply to the miners and traders who have been attracted to that region, and ultimately to the country at large. Full statistics are given of the sections covered by the report, and it may be noted that at Gloucester and Boston there has been a falling-off in the aggregate receipts of fish since 1896, while the South Atlantic States as a whole show an increase in the product, the amount of capital invested and the number of persons employed in the fisheries.

What strikes one very forcibly in glancing over this report is the many discouragements the fish culturist is called upon to face and the large number of serious losses due to unavoidable, often seemingly trivial and sometimes inexplicable, accidents. A few degrees of temperature, more or less, a heavy shower, the lingering of ice or an unfavorable wind may cause heavy damage and almost bring to naught the labor of weeks. Another thought is to what extent should the general government undertake the propagation and distribution of the more strictly game fishes, such, for example, as black bass and trout? The investigation of the best methods for the accomplishment of such work should undeniably lie with the United States, but these once discovered, its continuance should rest with States and individuals. What may be done by individual effort is shown by the fact that a large number of the many ponds of Plymouth county, Mass., have been stocked with black bass by the simple process of carrying a few fish in pails from one pond to another. It may be said that the establishment of many of the trout hatcheries has been due to the efforts of members of Congress and not to any desire of the Commissioner of Fisheries. The propagation of such widely-spread and all-important species as cod, shad, the Pacific salmon and the lobster is quite another matter and should properly be carried on by the United States.

The statistical as well as the strictly scientific work of the Fish Commission is again of national importance, and the special omission of fishery statistics from the coming census bears testimony to the value of the work done by this division.

It is gratifying to learn that the appropriation for scientific work has this year been materially increased, for, from past experience, we know that what to-day appears to be a purely scientific problem to-morrow becomes an all-important practical matter. In this connection Dr. Smith urges the appointment of an expert in fish pathology, calling attention to the large mortality which often prevails among fish, both under natural and artificial conditions, and for which there is at present no known cause or remedy. The annual losses at the hatcheries of the Commission, while not excessive, are still great enough to demonstrate the need of skilled investigation, and the present expenditure of a few thousand dollars may yield subsequent returns of millions.

Last, but not least, it may be again noted that under the present Commissioner it has been arranged to keep the laboratory at Wood's Hole under the scientific direction of Professor Bumpus open throughout the year.

ENGINEERING AND THE PROFESSIONS IN EDUCATION.

THE receipt of the annual volume of Proceedings of the 'Society for the Promotion of Engineering Education'* is a reminder of

* Proceedings of the Sixth Annual Meeting of the Society for the Promotion of Engineering Education, Vol. VI. Published by the Society. 1898. 8vo. Pp. xxvii + 324.

the extent to which all departments of education are becoming systematized and organized in the United States. Hitherto, in all countries, there had been observable a very serious lack in this respect, even in Germany, where the central government, and the authorities of every kingdom alike, control and direct the education of all classes from central organized bureaux.

With us primary and secondary education have had consistent and authoritative direction, not always wise or expert, but always earnest and well-intended; for the common school has been recognized, from the first, as the strongest bulwark of our institutions, political and social. Professional education and training, however, have, like all higher learning, been sustained mainly by private, sporadic and unsystematic, unauthoritative, support and aid. Education, in a true sense and on the lower levels, has been fairly well-cared for; professional training, that education which is rather a noble form of apprenticeship to a noble vocation, finds even yet almost no public and little private recognition. Of late the schools of engineering are securing some attention from investors in this form of higher security and from the State Legislatures and expert educators and professionals. In the West, particularly, the schools of the vocations are attracting more and more attention as their relation to and bearing upon the social condition of the people is coming to be generally appreciated.

The volume before us contains the proceedings of a single meeting of a representative association of this class, and presents a very excellent picture of the purposes and methods of such an institution. The Society, about five years old, numbers 244, and includes practically all of the leaders in the development of this branch of technical educational work in the country, and representatives from nearly all recognized professional schools in this field. Twenty-nine papers are published, together with lists of officers and members, the constitution of the Society, its rules and its proceedings at the Boston meeting of 1898.

The leading paper is the address of President Johnson, a discussion of the topic: 'A Higher Industrial and Commercial Education as an Essential Condition of our Future Material Prosperity.' This is a most interesting and impressive statement of the needs of the United States in this direction, and of the dangers that threaten a nation neglecting to systematize its industrial system and the education of the 'Industrial Classes' for their life and work in presence of a competition which is coming to be more constant and more dangerous as the means of communication and of transportation become more extended and more perfect. The foreign 'Mono-technic Schools' are held up to our view as models of a type of school which is almost unknown in this country, and as having proved the salvation of the Germanic peoples. The establishment of high-grade mono-technic and commercial schools is urged as the most promising and desirable of all visible modern improvements in education and training for the industrial classes.

A full evening was given to a paper 'On the Organization of Engineering Courses and on Entrance Requirements for Professional Schools,' in which the writer, following a somewhat similar line of thought, developed the theory of professional education, exhibited the logical differences between the real 'education' of the academic colleges and the primarily vocational training, the 'higher apprenticeship' of the professional schools; showing that while the one should offer a 'ladder from the gutter to the university,' as Huxley said, the other lets down a ladder from the profession to the people, the two thus demanding radically different methods of construction of

their curricula, as well as different methods of prescription of entrance requirements. The one supplements the schools, and must build smoothly up from below; the other builds down from the profession, and must, at all hazards, make its junction at the upper end effective, while its entrance requirements must be such as will least embarrass the aspirant while satisfying the proper demands of the profession. Each curriculum, however, must be constructed by experts in its own field, and the professional must be relied upon to perfect the courses and prescribe the requirements of the technical school, as must the expert in academic education be expected to be given a free hand in the upbuilding of general education.

Shorter papers on laboratory work, on details of educational apparatus, 'thesis work,' courses of instruction in various departments and reports of committees, fill the volume with a mass of material hitherto unparalleled in this line, and which must deeply interest, not only workers in this field, but all educators, and particularly all who are interested in the promotion and improvement of our still defective and inadequate educational provision for the best interests of the industrial classes, and in the advancement to still higher planes of our professional schools. The careful study, not of this volume only, but of the series, beginning with the organization of the Association at the Educational Congress at Chicago, in 1893, in connection with the Columbian Exhibition, cannot but well reward every one interested in the modern and current movements in this politically, as well as socially, important department of the scheme of national education, the perfection of which is so vital an element in determining what shall be the political and the moral and intellectual status of our country in coming generations.

R. H. THURSTON.

SCIENTIFIC BOOKS.

Die chemische Energie der lebenden Zellen. DR. OSCAR LOEW. Munich, Dr. E. Wolff, publisher. 1899. Pp. 170.

This publication gives the results of a series of observations on the chemical characteristics of living matter. It is proved that the proteids of living matter are of very labile nature and different from those of the dead matter, into which they are transformed by atomic migrations in the molecules. It is also demonstrated that in many plants a labile reserve-protein occurs which is not yet organized, but is changed by the same conditions as kill the cells. The book contains the following chapters:

1. Views on the causes of the vital activity.
2. General characteristics of living matter.
3. Chemico-physiological characteristics of living matter.
4. The essential concomitants of protoplasm.
5. The character of the biochemical work.
6. On the formation of protein in the lower fungi.
7. On the formation of protein in the green plants.
8. Theory of protein formation.
9. A labile protein as reserve material in plants.
10. Chemical characteristics of the labile protoprotein.
11. Lability and activity in the protoplasm.
12. Theory of respiration. Chapters 9 and 10 give the results obtained in conjunction with Th. Bokorny.

The most modern progress of theoretical chemistry has been brought to bear in this work. The theories advanced in the work and the suggestions which they contain will make the book invaluable to students of bio-chemistry and physiology. Doctor Loew has concluded his work with the following brief summary:

"It may be briefly recapitulated in a few words how much the theses put forth correspond or coincide with the observations made. In the first place, it should be remembered that the living substance shows a great resemblance to a chemically labile body and that the dying process of the protoplasm is suggestive of the transition of a labile into a stable modification of organic compounds. According to the theory developed in the eighth chapter concerning the formation of albumin, the lability of the plasma-protein is due to the simultaneous presence of aldehyde and amido groups. The

toxicological facts reported in the eleventh chapter, indeed, support this view.

The further inference from the theory, that very labile but not yet organized protein substances possibly occur in plants, has also been verified. An exceeding labile reserve protein of an aldehyde nature was proved by Bokorny and myself to exist in many kinds of plants; its characteristics are described in the ninth and tenth chapters.

Labile substances contain kinetic chemical energy; they contain certain loosely bound atoms, which under the influence of heat become more mobile than in case of a more stable arrangement. As a result chemical reactions are caused, the energy of these atoms being transferred to certain susceptible substances (sugar, fatty acids), which are thus drawn into a state of higher reactive power, especially with the otherwise indifferent oxygen of the atmosphere. In other words, catalytic actions are produced through a charge with chemical energy. The proteins of living substances appear as relatively firm structures in which separate labile atoms perform great oscillations. This conception is essentially different from that of Pflüger and Detmer, both of whom ascribe to all atoms in the plasma-proteins such an intense state of motion that a dissociation results, to be followed by a similarly energetic regeneration. Pflüger says: * "I do not expect to meet with any opposition if I consider the living matter as not only being astonishingly changeable, but steadily decomposing."

Yet, when we consider that a minimal attack of extremely small quantities of a poison will produce the death of a cell, one may well doubt whether such a metabolism as Pflüger assumes would not sooner lead to death than to a possibility of regeneration. Neither can we, therefore, agree with Verworn when he says: † "The life process is the sum-total of all processes connected with the building-up and destruction of the 'biogens,' or, "life consists in the metabolism of the albuminous bodies." A more correct definition would be the following: Life is the sum-total of the effects made possible by the labile nature of the plasma-proteins and their respiratory activity, and governed by the specific tectonic of the energides and of the active paraplastic structures.*

* Pflüger's Archiv 10, p. 311.

† Allgemeine Physiologie, 2d edition, p. 509.

The nature of the living matter is in the first place determined by lability and organization, that is, by a systematic kind of motion in a structure (tectonic) of labile proteins. The principle of organization is not yet known. Even if we assume with Pflüger that the process of organization consists merely in a polymerization, the complicated details in generation and karyokinesis, would still defy explanation, and the genetic differentiation would not become better intelligible. Difficult problems are here facing us. Still it may be considered a slight advance to know at least a little more about the cause of respiration and the chemical energy of the cells than formerly. It is the lability of the plasma-proteins, which, supported by the effects of light, leads to the building-up of the carbohydrates in the green plants out of carbon dioxide and water with separation of oxygen. It is also this lability which assists in combining the organic substances with oxygen and renders the obtained energy applicable to physiological work.

In addition to the well-known fact that all life functions are based upon the energies of the sun, it must be inferred that the lability of the plasma-proteins is necessary to transform this sun energy into vital action.

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Physical Geography. By WILLIAM MORRIS DAVIS, assisted by WILLIAM HENRY SNYDER. Boston, Ginn & Company. 1898. Pp. 431.

Professor Davis well states in his preface the central principle of this volume: "Physiographic facts should be traced back to their causes and forward to their consequences." We find thus the widest departure from the piecemeal description and recital of facts, of most works in physical geography. We should expect this from one who has long been eminent as a student and teacher of the science and who

* Kupffer designates the contractile substance of the muscular fibrille, the nervous fibre and the red blood corpuscles as 'paraplastic' formations.

has not ceased to magnify the causal notion and the consequent educational value of geography. It cannot hereafter be said that the materials of the new geography are not available to the rank and file of teachers, as was conceded in the report of the Committee of Ten. The limits of a secondary text-book forbid anything like a full discussion, and it is to be hoped that a manual or college text-book may come from the author's hand. He has discarded, for the most part, technical terms. Thus the doctrine of the peneplain is elucidated in the text, but the name appears only once, and that in a footnote. The rational geography makes large use of geology, but this has been done in a simple fashion which obviates the necessity of a previous course in that subject for the pupil, though the teacher would find such knowledge all but indispensable. To dwell for a moment longer on the pedagogical aspects of the volume, the vital teacher need not hesitate to use it, though he be deficient in preparation, but it is emphatically a book for the best, and only such can wholly do it justice. It wisely joins itself to the present state of knowledge, but leads well out among the ideals and possibilities of the science.

The illustrations are profuse and well selected. Especially useful are many diagrams which combine surface relief and vertical section, thus relating geographic form and geological structure. The appendix contains valuable bibliographic lists and a short catalogue of the best maps, whose use and importance are everywhere emphasized.

The Earth as a Globe, the Atmosphere, the Ocean and the Lands are the four main subdivisions of the book. All but the last are briefly treated, offering an outline of the chief facts in mathematical geography, meteorology and oceanography, terms which we think, for the present purpose, wisely discarded.

The lands are treated with greater fullness, the discussion occupying 273 pages. The chapter headings will best show the general character of this section. They are: The Lands, Plains and Plateaus, Mountains, Volcanoes, Rivers and Valleys, The Waste of the Land, Climatic Control of Land Forms, and Shorelines. The origin of these forms and their consequences upon organic and especially human life are never lost from view, and thus is realized the highest definition of geography as a study of the 'physical environment of man.' No separate sections are devoted to the races of man or the distribution of animals, but a reader of the whole volume will discover that these subjects have not been neglected, but have been treated in an intimate and educational fashion.

The principle of change of form by erosion and by change of relation to sea-level is early stated and receives manifold elucidation to the end. The Plain offers a good example of the author's method. We have first the formation of a coastal plain by deposition of land waste and uplift of marginal sea-bottom, with subsequent dissection by land streams. There logically follows the broader, higher, older and more dissected coastal plain, the eastern Carolinas serving as an example. The favorable conditions for artesian wells form here a naturally related topic. Embayed coastal plains show the effect of the later, partial submergence, the Chesapeake being used as a type. Such use of physiographic types, as a means of seeking and classifying examples in all parts of the world, is a favorite and important principle with our author. Similar plains of very ancient origin, as in central-southern Wisconsin and western New York, are then described and connected with the younger, less modified types, but without involving the difficult ideas or nomenclature of historical geology.

The plateau, or uplifted plain, appropriately follows. Thus we have young plateaus, as in Arizona; mature and well-dissected plateaus, as in the Catskill-Allegheny-Cumberland belt, and old plateaus, as recognized in the buttes, mesas and table-topped mountains of the West.

The treatment of mountains is, for the space, equally thorough and interesting. The various kinds are described—block mountains in various stages of maturity; folded and domed mountains, with such fruitful subtopics as climate of mountains, mountains as barriers, valleys among mountains, and inhabitants of lofty mountains.

The chapter on Rivers and Valleys well illustrates the strides of physiographic science dur-

ing the last score of years, as will appear from an outline of the chief topics. Thus we have young rivers, with lakes, falls and rapids as marks of immaturity; graded rivers and the development of valleys; meanders and the shifting of divides; mature and old rivers; revived, antecedent, engrafted and dismembered rivers, the causal or historical notion appearing at every stage of the discussion.

The general reader who desires to cultivate an appreciation for natural scenery will find help in Professor Davis's volume, and the student to whom most of the materials are familiar will find a convenient and systematic summary of the important facts and doctrines of a great and growing science.

ALBERT PERRY BRIGHAM.

COLGATE UNIVERSITY, February, 1899.

GENERAL.

The Bulletin of the American Mathematical Society states that advices from the Vatican announce that Abbé Cozza Luzzi, assistant librarian, has found Galileo's original manuscript treatise on the tides. The manuscript is in Galileo's handwriting and concludes with the words: 'Written in Rome in the Medici Gardens on January 8, 1616.' The currently accepted text, the original of which was supposed to have been lost, differs considerably from that of the manuscript just found. Pope Leo XIII. has taken the greatest interest in the discovery and has ordered the manuscript to be published in an elegant edition at the expense of the Vatican.

THE London *Times* announces that it will prepare a supplementary volume to the ninth edition of the Encyclopædia Britannica. This edition was published between 1875 and 1889. It is well known that the treatment of scientific subjects are in many cases the best accessible to English students, being prepared by leading English men of science. It is unfortunate that a new edition of the Encyclopædia cannot be prepared, as the last twenty-five years have brought many changes in all the sciences, but a supplementary volume will be of some service.

BOOKS RECEIVED.

A Handbook of Medical Climatology. S. EDWIN SOLLY. Philadelphia and New York. 1897. Pp. xii + 470.

Minerals in Rock Sections. LEA MCILVAINE LUQUER. New York, D. Van Nostrand Co. Pp. vii + 117.

Die Medial-Fernrohre. L. SCHUPMANN. Leipzig, Tuebner. 1899. Pp. iv + 145. Mark 4.80.

Die Lehre vom Organismus und ihre Beziehung zur Sozialwissenschaft. OSCAR HERTWIG. Jena, Fischer. 1899. Pp. 36. Mark 1.

Regeneration und Entwicklung. H. STRASSER. Jena, Fischer. 1899. Pp. 29. Mark 1.

Elementary Physiology. BENJAMIN MOORE. New York, London and Bombay, Longmans, Green & Co. 1899. Pp. ii + 295.

Primer of Geometry. JAMES SUTHERLAND. London, New York and Bombay. 1898. Pp. 117.

SOCIETIES AND ACADEMIES.

THE GEOLOGICAL CLUB OF THE UNIVERSITY OF MINNESOTA.

AT a meeting of the Club on February 25th Professor C. W. Hall discussed the extent and distribution of the Archean in Minnesota. First, accepting the Archean as that original 'crust,' or solidified portion of the earth, which is postulated in every existing view of the beginning of the geological record, he defined it as an era of igneous origins whose rocks represent the original crystallization of earth matter added to from below by successive solidification and many subsequent intrusions. By this definition all overlying clastics or irruptions into or through the clastics are excluded from the Archean. If the base of the clastics can be found there certainly should be found, locally, at least, the rocks upon which they lie. Such underlying rocks, the Archean, are believed to occur in Minnesota in two quite separated districts, the northern and the southwestern.

Along the international boundary most geologists have grouped all the rocks from Basswood Lake to Lake of the Woods as Archean, even when clastics have been clearly recognized and eruptives found breaking through them. Lack of care in delimiting the Archean upwards has caused much confusion. Lawson set an example in distinguishing between clastics, 'agglomerate schists' and the rocks underlying, though not necessarily those from which the clastics are derived. Structurally the

Archean of the Lake of the Woods forms a series of troughs—four is the number given—in which the Keewatin schists now lie. [Compare Geol. and Nat. Hist. Sur., Canada, N. Ser., Vol. I., 1885, C. C., pp. 10 et seq.] Although there are no sharp unconformities to be seen, yet, as Lawson observes, "the fact that we find in the Keewatin series the first undoubted evidences for this region of aqueous sedimentation and also of volcanic action, while in the underlying Laurentian gneiss of the region we find evidence of neither, more than suggests that the Keewatin series had a totally different kind of origin from that of the gneisses and must, therefore, be in unconformable relation to them" [Ibid., p. 84].

At Rainy Lake H. V. Winchell and Grant found a series of granites and granite gneisses beneath the other rocks (*i. e.*, Archean) and eruptive into them. Since these authors did not think best to distinguish between underlying and eruptive granite rocks their work is of but little taxonomic value. [Geol. and Nat. Hist. Surv., Minn., 23d An. Rep., 1895, p. 53.]

Between Rainy Lake and Lake Superior there are several belts of schists with alternating granites and other rocks having a general northeast-and-southwest trend. Concerning one of these, Irving noted in 1886 "that we have among the rocks * * * two types, in one of which the crystalline structure is complete and in which there is little or none of an original fragmental structure, while in the other the fragmental texture is still distinct and the alteration has progressed to a smaller degree." He then adds "that the supposed older one of the two groups of schists in the Vermilion Lake belt is intricately penetrated by the granites of the great areas north and south of the belt." [7th An. Rep. Director U. S. Geol. Sur., 1885–86, p. 437.] Hence areas of Archean lie north and south of these older schists.

In the Minnesota River Valley lies the most carefully studied series of granite gneisses, gneisses and gabbro schists of the State. These rocks occur quite continuously from New Ulm to Ortonville and beneath the glacial drift stretch westward into South Dakota and disappear beneath the Dakota sandstone. At New Ulm they clearly underlie a quartzite conglomerate regarded as Huronian (whether lower or upper is not determined). This Archean series is divided, for purposes of study, into a lower and upper; the former is named the Ortonville group of augite, hornblende and biotite granite-gneisses, and the latter the Granite Falls group of hornblende and biotite gneisses and associated gabbro schists. [Hall, Syllabus of Geology, 1897, p. 83.]

F. W. SARDESON,
Secretary.

THE BOTANICAL CLUB OF THE UNIVERSITY OF CHICAGO.

AT a recent meeting of the Club, Dr. Otis W. Caldwell gave the results of his study of *Lemna minor*. The following is an abstract of his paper: Owing to the greatly reduced body of the sporophyte of the Lemnaceæ there has been much interest in its morphology, and in the question as to the effect of the reduction upon the gametophyte. The investigations show that the sporophyte body is neither stem nor leaf, as often contended, but a shoot undifferentiated except at the basal or foot region and at the nodal region from which the root, the new shoots and the flowers arise. The root originates from a small group of hypodermal cells on the lower side of the node. The epidermis develops a temporary root sheath, while the persistent root cap is developed from the meristem, which is never many-celled and in a few cases was seen to be unicellular. Flowers are rarely formed, and frequently when they have begun to develop they are crowded out by vegetative buds which are produced in great abundance. Even when not encroached upon by vegetative shoots the flowers do not often succeed in forming seeds. The pollen grains usually become fully formed, but the structures of the ovule and embryo-sac may disorganize at any stage in their growth. Although the chief stages in ordinary embryo-sac development were found, such were shown by very few preparations; while in most of the preparations embryo-sacs were disorganizing, the disorganization first affecting the antipodals, then the polar nuclei or primary endosperm nucleus, the egg being the last to succumb to the unfavor-

able conditions. Cases were observed in which the upper polar nucleus, failing to fuse with the lower one, had proceeded unassisted to the production of endosperm. Few embryos were found.

In the young stamen but one archesporial mass appears. After this has enlarged somewhat a plate of sterilized tissue divides it into two regions, each of which is again divided in a similar manner, thus constituting the four archesporial masses of the anther. The four loculi of the anther are four parts of one sporangium, and not four sporangia, as reported usually for other spermatophytes. The primary tapetal layer is not differentiated until after the archesporium is separated into four masses. The tapetum may be derived either from the sporogenous tissue or from the adjacent sterile tissue. The cells of the tapetum frequently divide and push out into the cavity of the loculus, where they assist in nourishing the spore mother cells. Some of the latter are nourished also by other mother cells whose growth has ceased. The microspore germinates while within the sporangium. The generative cell remains closely applied to the wall of the spore for a considerable time before dividing to produce the male gametes.

The 'winter buds' seem to be summer buds which are not sufficiently vigorous to develop the necessary air spaces to keep them afloat. When conditions become favorable growth is renewed, air spaces develop in abundance, and the buds rise again to the surface.

It seems clear that *Lemna minor* has descended from terrestrial forms. The entire body of the diminutive plant, as evidenced by the disappearing root, the system for aeration, and the devices properly to relate the chloroplastids to the light, indicates attempts toward adaptation to the water habitat. It has not succeeded in working out such appropriate devices for pollination as are found in most water plants. The water environment also seems especially injurious to the embryo-sac structures of this plant, and the ease with which vegetative buds are produced, and the fact that some of these buds may serve to perpetuate the plant from year to year, reduces the necessity of seed production.

ENTOMOLOGICAL SOCIETY OF WASHINGTON.

UNDER the head of 'Short Notes and Exhibition of Specimens,' Mr. Benton stated that on January 22d he had found brood honey bees in all stages of growth and new adults, indicating egg laying the last of December. This is a very early instance.

Mr. Matthis exhibited specimens of what he takes to be *Boreus brumalis* Fitch, which he had caught upon the snow in the Rock Creek Valley after the recent blizzard. He showed for comparison specimens of a *Boreus* which he had caught last October at a high elevation on the Big Horn Mountains. This was a larger and darker form than *B. brumalis* and has not been specifically identified.

Dr. Dyar showed a blown larva of *Apatela clarescens* Gn., previously undescribed. The larva nearly resembles that of *A. hamamelis;* indeed, from the mature larva alone no constant differences can be pointed out, but Dr. Dyar has observed certain differences in the earlier stages of these larvæ, which will be more fully worked out at the next opportunity. In this connection, he also presented a list of *Apatela* by Professor A. R. Grote, with generic and subgeneric types, which had been prepared by Professor Grote on request, and which is supplemental to the monograph of the genus recently published by Smith and Dyar. Dr. Dyar stated that he was pleased with Professor Grote's erection of a subgenus for *A. funeralis*, since this was definable on larval character, as are all the other subgenera of *Apatela*, except *Tricholonche* as compared with *Lepitoreuma*.

Mr. Schwarz exhibited some very dry and hard pulp of the giant cactus, taken by Mr. Hubbard in the autumn of 1897 and containing specimens of the extraordinary Scolytid, *Cactopinus hubbardi* Schwarz. He had examined this pulp in January, 1897, and found the beetles alive, with no indication of oviposition. He moistened it somewhat at that time and showed the same beetles still alive, thus indicating that they may live in the adult condition for two years.

Mr. Howard showed a remarkably clear and beautiful photograph of *Phasgonophora sulcata* Westwood, which had been taken by Mr. M. V. Slingerland, and spoke briefly of the ad-

vantage of photography in entomological illustration, expressing the opinion that a fair photograph reproduced by the half-tone process is in many instances better than a poor drawing, but that the best photographs he had seen reproduced in this way were by no means equal to drawings made by competent artists. Such a photograph as the one exhibited, however, marks a great advance on previous efforts of the kind and would be invaluable at least as an aid to the artist, and if transferred by photography to a wood block and then handled by a competent wood engraver would obviate all necessity for drawing and would produce the most satisfactory results which could be obtained, since the slight failures in details could be easily rectified by the engraver.

Dr. Gill mentioned the resemblance of certain coleopterous larvæ to certain Trilobites, especially among the Staphylinidæ. He said he had been struck by this resemblance in a figure of a *Silpha* larva, even the antennæ resembling the antennae of Trilobites as recently discovered by Beecher. He mentioned the figure of Fluvicola, an Isopod crustacean, in De Kay's volume on the 'Crustacea of New York, and Le Conte's conclusion that it was the larva of *Psephenus*, and asked for further information as to this resemblance.

Mr. Schwarz said that this wonderful resemblance extends through several families of Coleoptera. He instanced *Micropeplus* among the Staphylinidæ, a genus of Scydmænidæ figured by Meinert, various genera of Endomychidæ, groups of species in the old genus *Silpha Psephenus* and *Helichus* among the Elmidæ, and various genera of the Dascyllidæ and Lampyridæ. The resemblance is largely caused by the exfoliation of the sides of the body. What its function is he did not know, some of the larvæ possessing it being aquatic, some subaquatic and some terrestrial.

The first paper of the evening, by Dr. Dyar, was entitled 'On the Fluctuations of the Post-spiracular Tubercle in Noctuid Larvæ.'

The second paper included a continuation of Mr. Hubbard's letters from the Southwest, presented with notes and comments by Mr. Schwarz. The letters read at this time related to the Colorado Desert and to Salton Lake and its insect fauna. Some discussion ensued on the question as to whether the Colorado Desert has been occupied at any modern period by an arm of the sea, Messrs. Vaughan, Schwarz and Gill taking part.

L. O. HOWARD,
Secretary.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

AT the meeting of the Academy of Science of St. Louis of March 6, 1899, Professor J. H. Kinealy described some experiments on lifting water by means of compressed air, as is done by the Pohle air-lift pump, and discussed the efficiency problems of the use of apparatus of this description. Three persons were elected to active membership.

WILLIAM TRELEASE,
Recording Secretary.

DISCUSSION AND CORRESPONDENCE.

THE IMPORTANCE OF ESTABLISHING SPECIFIC PLACE-MODES.

TO THE EDITOR OF SCIENCE—*Sir:* I use the word 'place-mode' to embody a well-known idea, namely, that a species has a different *mode* (*i. e.*, a different *prevailing* condition of size, color, etc.) in different localities. The person who seeks to determine a place-mode determines the prevailing dimension of the principal measurable qualities (and practically all qualities of organisms are measurable) of a species as it occurs in the locality in question.

The importance of this work is as follows: It fixes the condition of a species in a particular locality at a particular time; it affords a base from which we may measure any change which the species has undergone in the same locality after a certain number of years. That species in nature do undergo changes within a man's lifetime is recognized by some conchologists who find that certain shells of the seashore have undergone within a half century an evident change of index (ratio of length to breadth). A case of especial interest because of the exact measurements which have been made is that of the rock crab of Plymouth, England, the frontal breadth of whose carapace has diminished year by year at a measurable rate (1 to 2 per cent. in five years), a result explained by certain

changes in the physiography of the region (Weldon). Such facts indicate that species are changing in essential specific characters and sometimes rather rapidly changing. The changes are not sufficient to be detected in cases where the descriptions are wholly qualitative or based upon the observation of a few individuals. But where a large number of individuals, taken at random, are measured the modes may be used as standards for reference. With the aid of such standards we can observe not only the fact of change, but the rate and the direction, and draw conclusions concerning the causes of specific change. If two modes occur in a species in one locality we can determine whether they separate farther and farther from each other, and the rate of such separation. A careful correlation of the facts of separation of modes with changes in environment will give us an insight into the causes of specific differentiation. In a word, the establishment of these place-modes for various species in various localities is the first sure step toward the solution of the problem of the Origin of Species.

The methods of this work are very simple. They involve the measurement of size, of proportions and other elements of form, and of color, by the color wheel;* they involve also counting repeated organs. The measurements, or counts, are to be grouped into classes on the basis of size. The means of measurement will naturally be fonnd; but, most important of all, far more significant than the mean, is the *mode* or *the most frequented* class. The mode gives the typical condition of the lot of individuals measured.

The end of the old century or the beginning of the new one is a convenient time for making a number of these determinations, and it is on this account that I write to suggest to field naturalists that for a year or two they bend their efforts to the determination of place-modes. I am so convinced of the importance of this work that I am planning, with the cooperation of students, to work on this subject at the laboratory at Cold Spring Harbor during the coming summer, and I hope that simultaneous cooperative observations may be made at Woods Holl and other marine laboratories as well as at the various inland stations and by private collectors elsewhere. There is no fear of duplication of work, for two persons will hardly study the same species in one and the same locality.

Chas. B. Davenport.

Harvard University, March 2, 1899.

* The color wheel is an instrument for determining the percentage of constituent elementary colors in any compound color. A small, cheap and convenient form of this instrument—called the color top—with standard colors may be bought for six cents of The Milton Bradley Company, Springfield, Mass.

IDENTITY OF COMMON AND LABRADOR WHITEFISH.

The Common Whitefish of the Great Lakes was first very imperfectly described by Dr. Samuel L. Mitchill, in *The American Monthly Magazine and Critical Review* for March, 1818. The description, in fact, is so unsatisfactory that his contemporaries and later ichthyologists for more than fifty years supposed it to refer to the Cisco, or Lake Herring, *Argyrosomus artedi.* A good account of the Whitefish was published by Richardson in 1836, under LeSueur's name of *Coregonus albus*, a name published only a few weeks later than that of Mitchill; but, like Mitchill's, unaccompanied by a sufficient description.

In 1836 Richardson established a new species of *Coregonus* upon a dried specimen which he received from Musquaw River, that falls into the Gulf of St. Lawrence, near the Mingan Islands, giving it the name *Salmo* (*Coregonus*) *labradoricus*. This has been retained in the literature as a distinct species up to the present time, although its close relationship to the Common Whitefish has sometimes been observed without recorded comment.

Systematic ichthyologists have found it difficult to show clearly the differences between the Common Whitefish and the Labrador Whitefish, as may be seen by referring to the monographs upon the Whitefishes by Jordan and Gilbert, Bean, and Evermann and Smith. They have been forced to rely, finally, upon a single character, the presence of several rows of teeth on the tongue to distinguish the two forms, and this was supposed to be constant and infallible.

The writer has recently had occasion, while

studying the fishes of the State of New York, to examine numerous specimens of the Common Whitefish from the Great Lakes and interior lakes of New York and of the so-called Labrador Whitefish from lakes of New York and New Hampshire and from rivers in New Brunswick and Labrador. As a result of these investigations he is forced to the conclusion that Richardson's species, *Coregonus labradoricus*, is identical with the Common Whitefish, *Coregonus clupeiformis*, there being no characters by which the two can be distinguished. Every individual of the Common Whitefish, young and old, was found to have teeth on the tongue and to possess the other characters by which Richardson's species has hitherto been separated.

This conclusion has an important bearing upon fish cultural operations by the States and the United States, as it will tend to simplify the work of artificial propagation and, perhaps, extend its scope.

TARLETON H. BEAN.

WASHINGTON, D. C., March 3, 1899.

A DATE-PALM SCALE INSECT.

DR. A. S. PACKARD writes from Biskra, Algeria, January 23, 1899: "I find myself in this oasis of the northern edge of the Sahara, where there are 170,000 date palms. In a beautiful garden I found a date palm, indeed several, affected by Coccids, which I enclose." The Coccids are crowded on the pieces of leaf and prove to be *Aonidia blanchardi*, Targioni-Tozzetti, Mém. Soc. Zool. France, 1892, Vol. V., p. 69. The insect, however, is not an *Aonidia*, but belongs to *Parlatoria*, and must be called *Parlatoria blanchardi*. It was originally found in the oasis of Ourir, and has never, I believe, been noticed since its original description until now rediscovered by Dr. Packard.* The figures of Targioni-Tozzetti represent it well, except that in one of them (Fig. 3) there is an impossible lobule between the median interlobular squames. The female turns bright olive green on being boiled in caustic soda. There are four small groups of circumgenital glands. This insect is likely to be of some economic importance, as it is allied to, though easily distinguished from, *Parlatoria victrix*, Ckll.; which, introduced from Egypt, has proved a pest on date palms in Arizona, California and Queensland. The manner of the infestation is quite the same in the two species.

* Unless Maskell's *P. proteus* var. *Palmæ*, found in Australia on date palms imported from Algeria, is the same, as indeed seems likely.

T. D. A. COCKERELL.

MESILLA PARK, N. M., February 16, 1899.

THE CHOICE OF ELEMENTS.

TO THE EDITOR OF SCIENCE: Once upon a time, according, I believe, to Messrs. Gilbert and Sullivan, a magnet hanging in a shop window fell in love with a silver churn, but, to its great distress, was unable to awaken any response. Its pathetic plaint ran:

> "If I can wheedle
> A *nail* or a needle
> Why not a silver churn."

I used to think the magnet very unreasonable, because I supposed the atoms of iron and steel were necessarily drawn to it willy nilly, while there was no such tendency in the silver atoms, which were consequently quite unable to respond to its call. Major Powell (SCIENCE, February 17th) puts the matter in a new light, which awakens my sympathy for the magnet. It appears that the particles have choice. Both common sense and the dictionary tell us that choice is the power of choosing. Thus it was not of necessity, but of their free will, that the nails and needles were so responsive. The silver churn evidently considered the magnet ineligible. The case of the latter is a truly sad one, worthy of all serious commiseration, for if, as Major Powell tells us, the particles have intelligence, why should they not have love also? True, the magnet as a whole does not know, but what can assuage the grief of each of its myriad particles? Is there any hope that in time the silver will think better of it?

T. D.

HARVARD MEDICAL SCHOOL, February 27th.

ASTRONOMICAL NOTES.

TUTTLE'S COMET.

THIS comet was discovered by Méchain at Paris in 1790. Only a few observations were

taken, however, and the comet was rediscovered by Horace P. Tuttle at the Harvard College Observatory, January 4, 1858.

Johannes Rahts, of Königsberg, made the most complete discussion of the orbit, combining the observations of 1858 and 1871–2, having regard also to the perturbations. His value of the period is 13.7 yrs. The comet was next seen in 1885, and was expected during the present year. An ephemeris was accordingly distributed from Kiel, and it was probably by means of this that a faint comet, supposed to be Tuttle's, was discovered March 5th, by Dr. Wolf, as already announced. This ephemeris, as corrected by Dr. Wolf's observation, is given below.

Ephemeris.

G. M. T.			R. A.			Dec	
1899.	Mar.	5.5	1^h	16^m	39^s	$+31°$	$36'$
		9.5	1	31	31	+30	58
		13.5	1	46	31	+30	16
		17.5	2	1	35	+29	30

HARVARD COLLEGE OBSERVATORY,
March 8, 1899.

A NEW STAR IN SAGITTARIUS.

FROM an examination of the Draper Memorial photographs, Mrs. Fleming has discovered a new star in the constellation Sagittarius. Its position for 1900 is: R. A. = $18^h 56.2^m$, Dec. = $-13° 18'$. It was too faint to be photographed on eighty plates taken between October 18, 1888, and October 27, 1897, although stars as faint as the fifteenth magnitude appear on some of them. It appears on eight photographs taken while it was bright. On March 8, 1898, it was of the fifth magnitude, and on April 29, 1898, of the eighth magnitude. A plate taken this morning, March 9, 1899, shows that the star is still visible, and is of the tenth magnitude. Two photographs show that its spectrum resembles those of other new stars. Fourteen bright lines are shown, six of them due to hydrogen. The entire number of new stars discovered since 1885 is six, of which five have been found by Mrs. Fleming.

E. C. PICKERING.

HARVARD COLLEGE OBSERVATORY,
March 9, 1899.

NOTES ON PHYSICS.

ELECTRIC WIRE WAVES.

THE theory of electric waves along wires has been worked out very completely by J. J. Thomson for the case of a wire surrounded by a cylindrical conducting shell. A further development of the theory, together with some interesting numerical results is given by A. Sommerfeld in *Wiedemann's Annalen*, 1899, No. 2. The author gives a rigorous solution of Maxwell's equations for electric waves transmitted along a straight wire of great length. This rigorous solution leads to an equation in Bessel's functions, the roots of which give the velocity of transmission and the damping coefficients. The author gives approximate solutions of this equation for wires of great conductivity, diameter of wire being rather small compared to the wave-length, and for wires of medium conductivity, diameter of wire being very small compared to wave-length. In these two cases the equation in Bessel's functions reduces to a logarithmic form for which the roots may be found without serious difficulty.

The author gives the following calculated results: Electric waves of 30 cm. wave-length travel along a copper wire of 4 mm. diameter at a velocity which is less than the velocity of light by one part in 30,000, and the amplitude falls to $\frac{1}{2.8}$ of its initial value at a distance of 1.5 kilometers.

Electric waves of 100 cm. normal wave-length (period $33 \cdot 10^{-10}$ second) travel at about three-quarters of the velocity of light along a platinum wire .004 mm. diameter, and their amplitude falls to $\frac{1}{2.8}$ of its initial value at a distance of only 17 cm.

The author also gives a diagram of the lines of electric force inside and outside of the wire, the lines of magnetic force being circles around the wire.

W. S. F.

A NEW INDICATOR FOR ELECTRIC WAVES.

A GALVANOMETER of medium sensitiveness is connected to a battery, a strip of silvered glass is included in the circuit and the coating of silver is scratched across so as to break the circuit. The strip is placed in moist air and the galvanometer shows a deflection. When the strip is

exposed to electrical waves the galvanometer deflection is suddenly reduced to nearly zero; and when the waves cease the galvanometer deflection is quickly reëstablished. This effect is described by A. Neügschwender (*Wiedemann's Annalen*, 1899, No. 2), and the author finds that the film of moisture recovers its electrical conductivity so quickly after the cessation of the electrical waves that a telephone in circuit with the silvered strip gives the tone of the induction coil break even when the frequency of the break is very great. W. S. F.

THE ELECTRIC DISCHARGE IN RAREFIED GAS.

MATHIAS CANTOR (*Wiedemann's Annalen*, 1899, No. 2), has shown by means of the coherer (a mass of powdered metal forming a portion of an electric circuit), that the electric discharge produced through a vacuum tube by a large storage battery gives off electric waves. This discharge must, therefore, be either oscillatory or intermittent, contrary to the notion which has heretofore prevailed. W. S. F.

BRILLIANCY OF LIGHT SOURCES.

IN *Wiedemann's Annalen*, 1898, No. 13, Mr. P. Jenko gives a curiously roundabout method for the determination of the intrinsic brightness or brilliancy of light sources. Before entering into the details, however, it is necessary—such is the confusion of photometric terminology—to state a few definitions. The *brightness* of a source here signifies the total amount of light given out by that source and is ordinarily measured in candles. The *intensity of illumination* of a surface is the amount of light falling upon unit area of the surface and is usually measured in candles per square centimeter. Thus the intensity of the illumination of a surface distant one meter from a standard candle (assumed to give off light equally in all directions for the sake of brevity of statement) is $\frac{1}{126000} \frac{\text{candle}}{\text{cm}^2}$. This intensity of illumination is universally but irrationally called the *candle-meter*. The *brilliancy* of a light source is the amount of light given off from each unit area of its luminous surface. This, also, is to be expressed in candles per square centimeter. The candle per square centimeter is a convenient unit for expressing brilliancy of light sources, but is an inconveniently large unit for expressing ordinary intensities of illumination. Thus, easy reading requires about $\frac{1}{10000}$ candle per square centimeter.

Instead of determining the brilliancy of a light source by dividing its measured brightness (candle power) by the measured area of its luminous surface, making due allowance, of course, for irregular distribution in so far as this is possible, Mr. Jenko illuminates a screen of known area by a light of measured brightness, distance being measured. The intensity of the illumination of this screen is then known. He then compares upon a photometer bar the light given off by this screen with the light given off by the source of which the brilliancy is to be determined. He then measures the luminous area of the source and calculates its brilliancy in terms of the brilliancy of the illuminated screen, using an obvious relation between brilliancies, brightnesses and distances along the photometer bar! W. S. F.

THE MAGNETIZATION OF IRON.

IN *Wied. Ann.*, Band 66, No. 13, pp. 859–953, Max Wien communicates the results of a most careful and elaborate investigation upon 'The Magnetization of Iron by Alternating Currents.' The first part of the paper contains a general *résumé* of the literature of the subject, with a useful set of references to the original articles. Following this comes a discussion of the magnetization of iron by alternating currents, in which it is shown that for a coil containing an iron core and having a purely sinusoidal E. M. F. applied to it, neither the induction nor the magnetizing force will be a simple sine function of the time, but will contain higher harmonics, on account of the varying permeability of the core, and that also the apparent resistance of such an electro-magnet is greater than the resistance of its windings, while its apparent is less than its true self inductance.

A full description of the experimental arrangements and necessary corrections for Foucault currents, upper harmonics, etc., is then given together with the values obtained for the induction and hysteresis for irons of various qualities, using magnetizing currents having frequencies of 128, 256 and 520 per second.

The paper concludes with a general discussion of the experimental data, which may be summarized as follows:

The permeability and induction are always smaller for an alternating field than for a steady one, the difference reaching a maximum for low values of the magnetizing force, while near saturation the difference is small. For low values of the magnetizing force the differences are the same for all frequencies. The softer and less subdivided the iron, and the higher the frequency, the greater the difference (amounting in one case for very soft iron to 40%).

In moderate and strong fields, for equal values of the induction, the hysteresis is greater for alternating magnetization, than the value obtained by the usual static methods, the increase being greater the nearer saturation is approached, the higher the frequency and the softer the iron. The opposite is true for weak fields.

The only explanation which can be given is that the magnetism of the iron is unable to keep up with a rapidly varying field and consequently the hysteresis loop is broader and lower than it would be if determined for slow changes of the field. A. ST. C. D.

GENERAL.

H. BECQUEREL (Comptes Rendus, t. CXXVII., p. 899 and t. CXXVIII., p. 145) has been able to prove and study the existence of abnormal dispersion in sodium vapor. He finds that the effects of the D_1 and D_2 lines in causing abnormal dispersion are superposed and that for certain rays the refractive indices are less than unity.

ON account of its importance in the theory of atmospheric electricity the question as to whether the vapor of an electrified liquid is itself electrified is of great interest. It cannot be said that the subject has not received attention, but the results obtained by different investigators are not in accord. Pellat (Comptes Rendus, t. CXXVIII., p. 169) has lately reinvestigated the subject and finds that the rate of loss of charge from an insulated, electrified, metal vessel is greater when it contains water than when empty. Applying this result to the phenomena of atmospheric electricity he comes to the conclusion that it can only explain a part of the observed facts and further knowledge will reveal some as yet unknown cause acting. A. ST. C. D.

SCIENTIFIC NOTES AND NEWS.

MR. HENRY GANNETT, Geographer of the Geological Survey, who was the political and statistical geographer of the last census, has been asked to take charge of the same work for the coming census. The Director of the Census, Mr. Merriam, has announced that all applications for positions will receive consideration, and that examinations will be held as rigid as those before the Civil Service Commission. The 300 Supervisors are to be appointed after consultation with Senators and Representatives of the separate States, but without regard to party affiliations.

THE professors of geology in the University of California and in Stanford University have organized a geological club, to be called the 'Cordilleran Geological Club.' It is intended to include all the geologists of the Pacific and adjacent States, and its object is by occasional meetings to stimulate geological work. Whether it shall remain an independent organization or shall be affiliated with any other scientific body is left for future decision.

PROFESSOR RAY LANKESTER has been elected Foreign Correspondent of the Paris Academy of Sciences for the Section of Anatomy and Zoology. Twenty-seven votes were cast for Professor Lankester and eight for Professor Van Beneden, of Liège. M. Lortet, professor of medicine, of Lyons, has been elected National Correspondent for the same Section.

LORD LISTER, London, and Professor Koch, Berlin, have been elected Foreign Associates of the Paris Academy of Medicine.

PROFESSOR RAY LANKESTER, London; Professor L. Cremona, Rome, and M. Alexander Karpinsky, St. Petersburg, have been elected Associates of the Belgian Academy of Sciences.

THE address in medicine at the next Yale commencement exercises is to be delivered by Professor Charles Sedgwick Minot, of the Harvard Medical School. The title of the address has not yet been announced, but we are in-

formed that Dr. Minot will present some new aspects of medical education.

PROFESSOR GEORGE T. LADD, of Yale University, will be given a year's leave of absence at the close of the present academic year, and will lecture on philosophical subjects before the Universities of Japan and India.

DR. WILLIAM T. HARRIS, United States Commissioner of Education, has been given an honorary doctorate of philosophy by the University of Jena.

MR. W. E. D. SCOTT has been appointed curator of the ornithological collection in the School of Science of Princeton University.

MR. A. E. BOSTWICK, Librarian of the New York Free Circulating Library, has been elected Librarian of the Brooklyn Public Library.

THE Permanent Secretary of the American Association for the Advancement of Science, Dr. L. O. Howard, Department of Agriculture, Washington, D. C., would be glad to receive information of the present addresses of the following: Mr. William J. Lewis, Mr. Frank McClintock, Miss Mary A. Nichols, Mr. Charles M. Rolker and Mr. Carl H. Schultz.

SIGNOR RODOLFO LANCIANI, D.C.L., LL.D., professor of ancient topography in the University of Rome and Director of the Italian School of Archæology, has been appointed Gifford lecturer in the University of St. Andrews for the next two academical years. The subject of his lectures will be the 'Religion of Rome.'

WE learn from *Nature* that at the anniversary meeting of the Royal Astronomical Society, Mr. Frank McClean, F.R.S., was awarded the gold medal of the Society for his photographic survey of stars in both hemispheres, and other contributions to the advancement of astronomy. A prize of 500 francs, founded by Augustin-Pyramus de Candolle for the best monograph on a genus or family of plants, is offered in competition by the Société de physique et d'histoire naturelle de Genève. The monographs may be composed in Latin, French, German, Italian or English, and must be sent to M. Pictet, the President of the Society, before January 15, 1900. Members of the Society are not permitted to compete. The Belgian Royal Academy has awarded prizes of 600 francs to M. Georges Clautriau, of Brussels, for his memoir, on the macro- and micro-chemistry of digestion in carnivorous plants, and to Professor L. Cuénot, of Nancy, for his essay on the excretory organs of Mollusca.

WE regret to record the death of Sir Douglas Galton, F.R.S., the eminent sanitary engineer. Born in 1822, he was educated at Rugby and Woolwich, and received a commission in the Royal Engineers in 1840. He subsequently served in many important capacities as Inspector of Public Works, visiting the United States to inspect the railways in 1856. He was the author of books on 'Healthy Dwellings' and 'Healthy Hospitals.' Sir Douglas Galton was for twenty-five years the General Secretary of the British Association, and on his retirement, in 1895, was elected President. It will be remembered that his presidential address at Ipswich was published in this JOURNAL.

SIR JOHN STRUTHERS, emeritus professor of anatomy in the University of Aberdeen, died on February 24th, aged 75 years. He was the author of numerous papers on human and comparative anatomy, and exercised much influence on the improvement of anatomical teaching in Scotland.

THE deaths are also announced of Dr. Dareste de la Chavanne, the French anthropologist, and Dr. Franz Lang, a Swiss zoologist and geolgist.

A GRANT of £300 from the Worts Travelling Scholars' Fund, Cambridge University, has been made to Mr. W. W. Skeat, M.A., towards defraying the expenses of his scientific expedition to the Malay peninsula, on the condition that the results of the investigations made by the expedition be reported by him to the Vice-Chancellor in a form that may hereafter be published. Mr. Skeat is accompanied by two zoologists, Messrs. Evans and Annandale, of Oxford, and by Mr. Gwynne-Vaughan, botanist.

NEWS of the safety of M. Bonin, the French explorer, who has been missing in Thibet and the interior of China, has reached Shanghai. He arrived at Yachow, Sye Chuen district, after many exciting experiences, and will make his

way to the coast by the river route. With a few Chinese companions he has travelled through the greater portion of Thibet and made a trip from the Siberian line to Tong King.

Steps have been taken by the British government to guard against undue destruction of wild animals in Africa, by the issue of game regulations. The German government has been consulted, and it is proposed to hold an international conference on the subject in London in the spring.

The New York Post-Graduate Hospital has received $100,000 from Mr. Harris Fahenstock for a training school for nurses.

Professor R. W. Wood, of the University of Wisconsin, has discovered a new method of photographing in natural colors. He reproduces the colors by diffraction, and, though at present the production of the first finished picture is somewhat tedious, duplicates can be printed as easily as ordinary photographs are made The pictures are on glass, and are not only colorless, but almost invisible when viewed in ordinary lights, but when placed in a viewing apparatus, consisting of a convex lens on a light frame, show the colors of nature with great brilliancy. The principle is that the picture and the lens form spectra which overlap and the eye placed in the overlapping portion sees the different portions of the picture in color depending on the distance between the grating lines at that place. Professor Wood says the finished picture is a transparent film of gelatine with very fine lines on it, about 2,000 to the inch on the average. The colors depend solely on the spacing between the lines, and are pure spectrum colors, or mixtures of such, the necessity of colored screens or pigments, used in all other processes except that of Lippman, having been overcome. The pictures can be projected on a screen by employing a suitable lantern, or can be viewed individually with a very simple piece of apparatus consisting of a lens and perforated screen mounted on a frame. A peculiarity of the process is that there is no such thing as a negative in it. Half-a-dozen pictures have been printed in succession, one from another, and all are positive and indistinguishable from each other.

The record for kite-flying for scientific purposes has again been broken at the Blue Hill Observatory; 12,440 feet above the sea-level was reached on February 28th by a recording instrument attached to a string of tandem kites. This is 366 feet higher than the preceding best record, made at the same place on August 26th. The flight was begun at 3:40 p. m., Tuesday, the temperature at the surface being 40° and the wind seventeen miles an hour. At the highest degree the temperature was 12° and the wind velocity fifty miles an hour. Steel wire was used as a flying line, and the kites, four in number, were of an improved Hargreave pattern, with curved surfaces, made after the pattern of soaring birds' wings. The upper kite carried an aluminum instrument weighing four pounds, which recorded graphically temperature, wind velocity, humidity and atmospheric pressure. The combined kites had an area of 205 square feet and weighed twenty-six pounds, while the weight of the wire was seventy-six pounds. The upper kite remained above two miles for about three hours, and was reeled in by a steam windlass, constructed for that purpose. When within half a mile of the ground the fastening on one of the kites slipped, and this carried it up to the one above, the added pull snapping the wire and sending three kites adrift. A search for the lost kites was begun on Wednesday, and two of them were found at the Milton town farm, about two miles away, but the third was not recovered until later, when it was found at Field's Corner, over six miles north of the Observatory, or more than half the distance between that point and the State House. The recording instrument was found uninjured. This was the last of a series of five high flights made on successive days, Sunday excepted. The average height reached was 10,300 feet, or nearly two miles. The temperature at 10,000 feet on February 23d was 5°; on the 24th, 1°; on the 25th, 11°, and on the 28th, 20° above zero.

The *British Iron Trade Journal* attributes the remarkable expansion of the iron and steel industries of the United States to the following favorable changes in economic conditions: (*a*) 'Intensive' production, reducing costs generally; (*b*) Reduced costs of ores and develop-

ment of the deposits of fine mineral in the district adjacent to the Great Lakes; (*c*) Reduction of salaries through technical progress and changes in systems of administration; (*d*) Remarkably low cost of fuel; (*e*) Concentration of production with unlimited capital; (*f*) Mainly, however, to reduced cost of transportation. This last factor more than all others together has brought about this great change and placed the United States in its present relation to the world's markets.

IN a note by M. Considère, published in the *Moniteur Industrielle*, recently, there are given the data of tests of mortars and cements in structures, their resistance being reinforced by the introduction of iron straps and 'armatures,' which show that, as he states, these substances may be thus caused to sustain tensions twenty times as great as when not thus reinforced.

IT appears that the Nernst light, the scientific principles of which we recently described, is likely to rival the arc lamp for general use. Companies have been organized in Germany, Great Britain and America with capitals extending into the millions of dollars. The English company values its rights at about $1,300,000, and it is to be hoped that Professor Nernst receives the greater part of this sum.

Knowledge states that a site has been secured at Kemp Town, overlooking Queen's Park, Brighton, for the Gardens of the recently founded Zoological Society for Brighton and Hove. Some sixty years ago Brighton possessed a small zoological garden situated north of The Level, on the Lewes Road. The institution did not flourish owing to the ignorance of its originators, who had no notion of the proper method of dealing with captive specimens. The consequence was a very high death-rate and a brief career for the institution. The new garden will not be likely to fail from the causes which produced the collapse of its predecessor, for it will be managed by competent zoologists who have experience in the treatment of animals of all kinds. Moreover, the encouragement held out to the projectors by residents and persons of distinction in Brighton is such as to warrant us in believing that the undertaking will prove to be a success in all respects. A special feature in the new institution will be the regular delivery of courses of instructive popular lectures for the benefit of the numerous schools in Brighton and Hove. Among those who have enrolled their names as patrons of the Society are several of the foreign Ambassadors, the Duke of Fife, Sir John Lubbock, Sir Edward Sassoon, the Earl of Chichester and the Hon. Walter Rothschild. The managing-directors are the Earl of Landaff and Mr. F. W. Frohawk.

THE New York *Medical Record* states that the Japanese parliament has passed a bill authorizing the free distribution of vaccine virus and rendering vaccination compulsory. It is provided that a child must be vaccinated within ten month of its birth, and that, if the vaccination does not take, it must be repeated within a period of six months, and yet again within a similar period if it be again unsuccessful. Further, all children must be re-vaccinated at the age of six and once more at the age of twelve. Thereafter vaccination becomes occasional, and may be declared compulsory at any time of threatened or actual epidemic, the power to order it being vested in local governors.

A COURSE of nine lectures upon science and travel has been arranged by the Field Columbian Museum, Chicago, for Saturday afternoons in March and April at 3 o'clock. The lectures are as follows:

March 4—'Cuba and the Cubans,' Dr. R. S. Martin, Chicago.

March 11—'Blind Fishes of North American Caves,' Dr. Carl H. Eigenmann, Director, Biological Station, Bloomington, Indiana.

March 18—'Religious Ceremonies of the Hopi Indians of Arizona,' Dr. George A. Dorsey, Curator, Department of Anthropology, Field Columbian Museum.

March 25—'Colors of Flowers and Fruits,' Professor W. H. Dudley, Wisconsin State Normal School.

April 1—'Russia and the Russians,' Professor A. M. Feldman, Armour Institute of Technology.

April 8—'The Bad Lands of South Dakota,' Professor O. C. Farrington, Curator, Department of Geology, Field Columbian Museum.

April 15—'Extinct Vertebrates of the Bad Lands,'

Mr. E. S. Riggs, Assistant Curator of Paleontology, Field Columbian Museum.

April 22—'Animal Messmates and Parasites,' Professor H. M. Kelly, Cornell College, Mount Vernon, Iowa.

April 29—'Aboriginal Methods of Manufacturing Weapons and Implements,' Professor George L. Collie, Beloit College, Wisconsin.

UNIVERSITY AND EDUCATIONAL NEWS.

MR. W. F. R. WELDEN, F.R.S., professor of zoology of University College, London, has been elected Linacre professor of comparative anatomy at Oxford, in succession to Professor Ray Lankester. Professor Welden, Professor Love, whose appointment to the Sedleian chair of natural philosophy we announced last week, and Mr. Stout, recently appointed to the Wilde lectureship of mental philosophy, were all Fellows of St. Johns College, Cambridge.

THE following promotions have been made at Princeton University: Assistant Professor Herbert S. S. Smith to be professor of applied mechanics in the School of Science; Assistant Professor Walter Butler Harris to be professor of geodesy in the School of Science, and Instructor Ulric Dahlgren to be assistant professor of histology in the academic department.

E. L. THORNDIKE, PH.D. (Columbia), instructor in Western Reserve University, has been appointed instructor in genetic psychology in Teachers College, Columbia University.

THE Isaac Newton Scholarship of Cambridge University for the encouragement of study and research in astronomy has been awarded to Mr. G. W. Walker, B. A. Scholar of Trinity College. The scholarship is of the annual value of £200, and is tenable for three years.

MISS CAROLINE HAZARD, of Peacedale, R. I., has been elected President of Wellesley College.

PROFESSOR SNELLEN will retire at the close of the present semester from the chair of ophthalmology at the University of Utrecht.

AT a recent meeting of the Council of New York University Chancellor MacCracken reported that endowments amounting to nearly $50,000 had been received, of which $20,000 will be devoted to the School of Applied Science.

A CHAIR of English Literature has been endowed in Princeton University with $100,000, on condition that the Rev. Dr. Henry Van Dyke, of New York City, be the first incumbent. Princeton University has also received $65,000 for the academic department.

THE German-American citizens of New York are collecting a fund of $20,000 in honor of Mr. Carl Schurz, whose seventieth birthday was recently celebrated. The money will be used to endow a fellowship and a Library of Germanic Literature in Columbia University.

THE following further gifts have been made during the week to educational institutions: $50,000 to the Catholic University by the National Council, Knights of Columbus, to establish a chair for historical research; $20,000 to Hobart College for the foundation of scholarships by Miss Catherine L. Tuttle; $10,000 to University of Virginia for books on the history of Virginia, and $5,000 from various donors to Syracuse University.

AT congregation at Cambridge University on March 2d the report of the General Board of Studies recommending the establishment of a department of agriculture in the University under the direction of a professor was approved. The offers made to the University by Sir Walter Gilbey, the Board of Agriculture, certain county and borough councils and the Drapers' Company were gratefully accepted.

THE plans for the Cornell Medical School, New York City, have been filed. The entire frontage on First avenue, between Twenty-seventh and Twenty-eighth streets, is to be occupied by the building, which will cost $500,000.

Erratum: In the abstract (p. 312 above) of Professor Wm. A. Locy's paper before the American Morphological Society, 'New Facts Regarding the Development of the Olfactory Nerve,' the first sentence should read: 'The early embryonic history of the olfactory nerve is very imperfectly known,' instead of 'is known,' and the closing sentence should read: 'It was also shown to persist in the adult,' instead of 'to perish in the adult.' Credit should also be given to the Elizabeth Thompson Science Fund for providing the material upon which the research was conducted.

Othniel Charles Marsh, Professor of Paleontology in Yale University, President of the National Academy of Sciences from 1883 to 1896, President of the American Association for the Advancement of Science in 1878, and one of the editors of this Journal, died at New Haven on March the eighteenth, in his sixty-eighth year.